MIDDLE (HYALITE) CREEK DAM REHABILITATION FEASIBILITY STUDY

Prepared For:

MONTANA DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION
32 SOUTH EWING HELENA, MONTANA

Prepared By:

FEBRUARY 1985
8M087.113

HKM ASSOCIATES
ENGINEERS·PLANNERS

executive plaza*airport industrial park
p.o. box 31318, billings, montana 59107
(406) 245-6354

1842 SUGARLAND DRIVE
SHERIDAN, WYOMING 82801
(307) 672-9006

202 EAST SIXTH STREET
LIBBY, MONTANA 59923
(406) 293-3513

HKM Associates
Middle (Hyalite)
Creek Dam
rehabilitation
feasibility study

MIDDLE (HYALITE) CREEK DAM

REHABILITATION FEASIBILITY STUDY

Prepared For:

Montana Department of Natural Resources
and Conservation
32 South Ewing
Helena, Montana 59620

Prepared By:

HKM Associates
P.O. Box 31318
Billings, Montana 59107

February 1985
8M087.121/0739H

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SUMMARY

MIDDLE (HYALITE) CREEK DAM
REHABILITATION FEASIBILITY STUDY

LOCATION

Middle Creek Dam is located on Hyalite Creek approximately 14 miles south of Bozeman, Montana in Gallatin County. The dam, reservoir and contributing drainage are within the boundary of the Gallatin National Forest.

ORGANIZATION

Middle Creek Dam is owned by the state of Montana and is administered by the Water Resources Division, Department of Natural Resources and Conservation (DNRC). The Middle Creek Water Users Association (MCWUA) contract with DNRC for storage water. The MCWUA is responsible for repaying capital investments and operating and maintaining the dam in exchange for release of storage water from the dam. The financial status of the MCWUA is excellent. O&M assessments are less than $1.00/AF and most debt is paid.

PROPOSAL

Loan (40-year repayment)		$2,994,000
Grant (Federal)		470,000
State Contribution		807,000
Water rights	$ 10,000	
Feasibility Report	300,000	
Filing Fee	1,000	
Grant (State)	496,000	
Total Project Cost		$4,271,000

PLAN

Purpose

The spillway capacity of Middle Creek Dam does not meet present dam safety standards. A breach of the dam embankment could occur as a result of overtopping during a large flood event. Damages from the resulting flood could exceed $30 million plus the cost of repairing the dam. The purpose of this rehabilitation is to provide spillway capacity to pass the PMF, provide additional storage capacity and to rehabilitate the existing principal spillway system.

Physical Works

The principal project features are:

1. An earthen auxiliary spillway excavated in the left abutment, which is 530 feet wide at top transitioning to 37 feet wide at its end.
2. Enlargement of the dam embankment by 10 feet using reinforced earth in the center of the dam and conventional earthfill on the ends.
3. Increase the normal water surface by 8.2 feet (from top of existing flashboards), enlarging the active reservoir capacity from 8,267 AF to 10,184 AF providing an additional 1,917 AF of storage. All of the storage not presently contracted (2,374 AF) will be allocated to municipal use.
4. Provision of an inlet wier and concrete chute liner in the existing spillway, a new stilling basin, and a channel and dike leading to a new drop structure to Hyalite Creek. The existing bridge will be replaced.
5. Riprap of the outlet conduit discharge area and minor improvements to the outlet works system.
6. Relocation of campground facilities, boat ramp, roads and other facilities affected by the rehabilitation.

Project Costs

Principal Spillway	$ 745,700
Auxiliary Spillway	231,700
Dam Enlargement	1,127,200
Access Roads	121,800
Environmental Mitigation	75,000
Subtotal	$2,301,400
Contingencies	575,350
Project Cost Inflation 1984-1986	431,500
Engineering and Administration	472,750
Interest During Construction (Municipal Share)	120,000
Water Rights	10,000
Lendor Participation	60,000
Construction Cost	$3,971,000
Feasibility Report	300,000
Total Project Cost	$4,271,000

LAND

Service Area 14,912 Acres

Irrigated Area 8,950 Acres

Land Use

Alfalfa - Grass Hay	37.5%
Barley	22.5%
Winter Wheat (Dryland)	15.0%
Pasture, Subirrigated	15.0%
Summer Fallow	7.5%
Homestead Etc.	2.5%

Interest-bearing Lands (Under P.L. 984 Program)

Excess Land	None
Small Tract Lands	177 Acres - Bears interest
Commercial Irrigation	8,773 Acres - Does not bear interest

WATER

Water Supply (Average Year)

	Acre-Feet
Reservoir Inflow (May & June)	18,000
Reservoir Direct Flow Bypass (May & June)	1,000
Storable Flow (May & June)	17,000
Reservoir Yield (9 of 10 years)	10,200

Water Use (year 40)

Supplemental Irrigation	5,005
Municipal (City of Bozeman and Small Tracts)	5,179

Assuming that the City of Bozeman grows in population from its present 22,000 to 35,000 by year 2020 and the efficiency of the city's system is improved 20%, the additional 2,374 AF of storage provided by this project will satisfy the needs of the city. The city currently holds 2,805 AF of storage in Hyalite Reservoir. Estimated yield of rights held by the city from other sources (Lyman Creek and Bozeman Creek) provide 5,462 AF of water.

Water Rights

Storage rights held by the state of Montana in Hyalite Reservoir have a priority date of July 12, 1938 and are junior to over 97% of the claimed direct flow rights in the basin. Except for May and June, inflows to the reservoir normally are released to meet the demands of the senior direct flow rights. Historically, the reservoir has filled nearly every year. Storage occasionally occurs in other months during brief storm runoff periods.

Modeling of the basin indicates that the additional storage in May and June will not adversely affect prior appropriators. Water right applications are presently being processed.

PAYMENT RESOURCES

Funding for this project is expected from two sources described as follows:

- A loan and grant through the Small Reclamation Projects Act (Public Law 84-984) administered by the Bureau of Reclamation, U.S.D.I. One of the requirements of this program is that irrigators repay their share of the loan without interest but must pay 100% of their "payment capacity". Analysis by USBR guidelines indicates no "payment capacity". However the irrigators have indicated a "willingness to pay" $5.00/AF which, on a cash flow basis, is available from returns to management, labor and equity. Municipal users must repay their share of the loan with interest. The municipal assessment will equal $35/AF which is based upon the least cost alternative. A grant of $470,000 is requested based on recreational use of the reservoir.

- A state grant of $496,000 is requested based on recreational benefits and dam safety benefits to the public.

SUMMARY OF FINANCIAL PROGRAM

Period of Repayment	40 years
Interest Rate	10-7/8%

ANNUAL ASSESSMENT SCHEDULE ($/AF)

	Municipal	AG
P.L. 984 Loan Repayment	$34.00	$4.00
O,M&R	1.00	1.00
Existing Debt	-0-1/	-0-
Emergency Fund	-0-2/	-0-
	$35.00	$5.00

1/ Most debt is paid.
2/ An adequate emergency fund is established.

CHAPTER I
GENERAL INFORMATION

INTRODUCTION

This investigation was completed on Middle Creek Dam to determine what measures should be undertaken to make the dam safe. Other problems, not relating to safety, were also addressed as a part of this study. Middle Creek Dam (Hyalite Reservoir) is owned by the State of Montana and administered by the Montana Depart of Natural Resources and Conservation (DNRC). It is operated by the Middle Creek Water Users Association (MCWUA).

A Phase 1 investigation completed by the Corps of Engineers, Seattle District, in April 1980 revealed that the dam cannot safely pass one-half the probable maximum flood (PMF). Field inspection and preliminary hydrologic analyses indicated that the dam does not conform to inspection guidelines with respect to discharge and does not have the storage capacities needed to pass the recommended spillway design flood. There is considerable potential for loss of life and destruction of property if the dam should breach by overtopping during a large flood.

The Corps made the following recommendations:

> "A downstream warning system, for use in the event of possible dam overtopping or structural failure, must be developed and implemented immediately. Remove flashboards from the spillway. Conduct more detailed hydrologic and hydraulic routing studies to better determine the downstream hazard and required spillway capacity, and modify the project as studies indicate.

Investigate source of left abutment seepage by the installation of piezometers and study of the data. Sample and test the embankment and foundation soils and conduct stability analyses using piezometric data.

Conduct periodic inspections of the facility at intervals not to exceed 5 years by engineers experienced in dam design and construction."

A subsequent feasibility study was made by HKM Associates of Billings under contract with DNRC. The resulting report details an engineering plan and describes the financial arrangements needed to solve the safety concerns and other problems identified in the Phase I report. Throughout this report the reader will be referred to four other supporting reports which have been completed as follows:

1. Hydrologic Potential For Hyalite Creek Watershed, HKM Associates, November 1983.

2. Geotechnical Investigation, Middle Creek Dam, HKM Associates, April 1984.

3. Flood Hydrology, Middle Creek Dam, HKM Associates, April 1984.

4. Probable Maximum Flood Damage Estimates, ECO Northwest, Inc., June 1984.

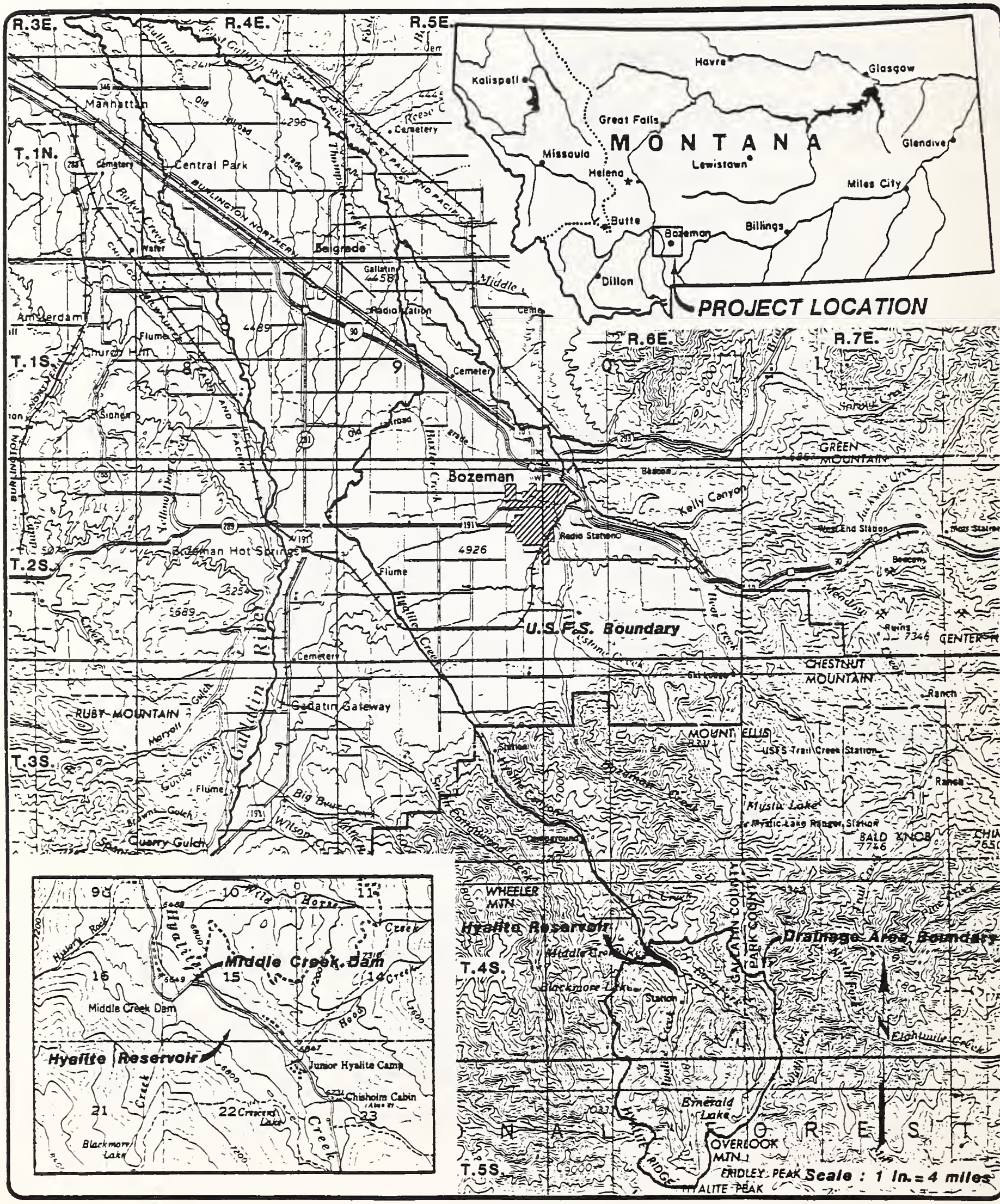
These four reports are summarized in this report. The reader should refer to them if additional detail is needed.

DAM LOCATION AND PHYSIOGRAPHY

Middle Creek Dam is located on Hyalite Creek approximately 14 miles south of Bozeman, Montana; slightly inside the northern border of the Gallatin National Forest. (See Figure I.1) The dam and reservoir occupy portions of Sections 15, 22 and 23, T4S, R6E in Gallatin County. The project has an approximate latitude and longitude of 45 degrees, 30 minutes and 111 degrees, respectively.

A 27-square-mile drainage basin feeds the storage project. The basin lies in the Gallatin Range of the Rocky Mountain Physiographic Division (Missouri Basin Inter-Agency Committee, 1971). Elevations within the study basin range from approximately 6,700 feet National Geodetic Vertical Datum (NGVD) at Middle Creek Dam to approximately 10,300 feet NGVD along the Hyalite Ridge which forms the southwestern divide of the contributing watershed. An area-altitude analysis was performed using 15-minute USGS quadrangle maps to characterize the watershed (see Flood Hydrology Report, April 1984). The results show that nearly two-thirds of the contributing watershed fall within the 7,000- to 9,000-foot range. Mean basin elevation above the dam is 8,324 feet NGVD. A drainage area summary for the Hyalite Creek Basin is provided in Table A2, Appendix A of the Flood Hydrology Report.

The watershed is nearly rectangular in shape. The East and West Fork drainages of Hyalite Creek have limited flow records above Hyalite Reservoir. Both forks of Hyalite Creek drain in a northerly direction above the gages. The 7.6-square-mile contributory area between the gages and the dam is elongated in the transverse direction. The drainage basin downstream of the dam but upstream of the Ranger Station gage again assumes an elongated shape.



MIDDLE CREEK DAM REHABILITATION

GENERAL LOCATION MAP

8M087.113

SEPTEMBER 1984

FIGURE I.1

HKM ASSOCIATES
ENGINEERS-PLANNERS

The drainages above the dam are characterized by steep, rugged terrain along the divides, and talus slopes from the exposed rock faces to the stream channels. There are a few high-mountain lakes in both drainages, and there are scattered clear-cut zones due to timber harvesting. The terrain, climate and soil conditions play an important role in the basin hydrology. A significant amount of precipitation is either absorbed into the soil to be consumptively used by the vegetative cover, is temporarily lost to the subsurface strata and later shows up as streamflow, or is permanently lost to deep percolation. Overland flow in these mountain drainages is minimal.

Hyalite Creek flows approximately 9 miles through a steep, narrow canyon until leaving the Gallatin Range. Hyalite Creek then flows northwesterly and northerly for about 17 miles before joining the East Gallatin River. The East Gallatin River is a tributary of the Gallatin River which, in turn, is a tributary of the Missouri River. Hyalite Creek is slightly incised in the valley alluvium as it travels from the canyon mouth to the East Gallatin River.

CLIMATE

Reservoir Basin Climate. Climate of the Hyalite watershed can be classified as moist subhumid (Missouri Basin Inter-Agency Committee, 1971). Similar to other subbasins in the Gallatin River Basin, the Hyalite watershed typically receives its least precipitation in the summer months of July and August, and the most precipitation in April through June. September generally initiates an increase in precipitation due to fall rainstorms, with snowfall occurring in subsequent months. The snowfall contributes to winter snowpack accumulation in the upper watershed. Significant snowmelt above Middle Creek Dam

generally does not begin until late April and can last until the early part of July. Storms in the form of rain, snow, or snow-mixed-with-rain contribute to the peak precipitation months in the spring.

The climate of the Hyalite Reservoir Watershed is discussed in detail in Hydrologic Potential For Hyalite Creek Watershed, HKM 1983 and Middle Creek Dam Flood Hydrology, HKM 1984.

Agricultural Service Area

Precipitation and temperature patterns of the agricultural service area are recorded by the Bozeman climate station located at Montana State University. The mean annual precipitation (1931-1982) at the MSU station is 18.4 inches. Historic precipitation measurements (1931-1982) for the Bozeman station are provided in Table IV.1. Temperatures in the service area follow a diurnal pattern and exhibit definite daily and seasonal variations. Average temperatures at the Bozeman station vary from 20.8° fahrenheit (°F) in January to 66.7°F in July. Wintertime temperatures are consistently below freezing, with occasional severe cold spells and warm chinooks.

The growing season for alfalfa starts when the spring mean daily temperature reaches 50°F and ends with the first occurrence of a 28°F killing frost. Spring grains have a growing season from 45°F mean daily temperature in the spring until maturity approximately 130 days later.

The last occurrence of 28°F temperatures in the period 1931-1982 varied between April 12 and June 8. The first occurrence of 32°F temperatures during the same period varied from July 2 to October 30. The average growing season during 1931-1982 was 144 days for alfalfa and 131 days for barley.

The most damaging storms are hailstorms which occur most frequently in July and August, and less frequently in June and September. Tornadoes develop very infrequently in the Bozeman area. Severe drought is very uncommon (Climates of the States, NOAA 1974) for the Bozeman area.

CHAPTER II
MONTANA DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION (DNRC) AND MIDDLE CREEK WATER USERS ASSOCIATION (MCWUA)

BACKGROUND

Since DNRC administers Middle Creek Dam, the agency will be the legal contractual entity with the lending institution when financial arrangements are made to underwrite rehabilitation of the project. DNRC will in turn contract with the water users for repayment of the loan. A brief explanation of the background of water projects in Montana will be useful in understanding the ramifications of these transactions.

The history of state-owned water projects began during the drought-depression days of the 1930s. These projects were built with federal assistance from the Public Works Administration. About 40 water storage or distribution systems have been constructed in Montana under the direction of the State Water Conservation Board, which was formed in 1935. These projects provided emergency employment and, most importantly, helped to stabilize the agricultural economy. They marked a shift to predictable sources of water for irrigated farming.

Responsibility for operating and maintaining the projects was assumed by the Water Conservation Board. When the Board was replaced in 1967 by the Montana Water Resources Board, the new agency added several related activities. Engineering services were provided for local water users associations to assist in operation and maintenance (O&M) and annual inspections of

previously constructed projects. Gradually the water users associations have assumed responsibility for operation and maintenance, with the state agency serving in a supervisory capacity.

Changes have continued to take place. When state government was reorganized under a new state constitution in 1971, the Montana Water Resources Board was replaced by the Department of Natural Resources (DNRC). The Department's Centralized Services Division was originally given the responsibility for accounting and billing for the projects. That duty has now been assumed by the Department's Engineering Bureau.

Most projects are administered through water marketing and water purchase contracts with the local water users association. A water marketing contract is a two-party agreement between the Department and an association, which states the association's obligation to sell water, collect payments from the users and repay the state's investment. Under most of these contracts there is no provision for the association to own a project when it is paid off. A water purchase contract is a three-party agreement between an individual water user, the association and the Department. It sets forth the conditions of water delivery to the water user and the terms of payment for the water. The amount paid is proportionate to the amount of water received, and consists of a principal payment, which is applied toward repayment of the state's investment, and an O&M payment, which is used by the water users association for operation and maintenance of the project.

On several projects, the state has extended loans to the associations for major repairs. These loans are repaid by renegotiating the original water marketing and water purchase contracts or by entering into a special repayment contract between the association and the Department.

Status of the state's investment as of June 30, 1976 is outlined by project in Table II.1.

Table II.1

TABLE 2

RECOVERY OF STATE INVESTMENT FROM INCEPTION TO JUNE 30, 1976

Project Name	Outstanding Investment 6/30/76[a]	Receivables, 6/30/76			Status of State Investment, 6/30/76	
		Water Purchase Contract[b]	Repayment Contract[c]	Total	Potential State Revenue Exceeding Investment	Not secured by Current Contract
Ackley Lake	61,518.37	15,204.00	3,079.58	18,283.58		43,234.79
Broadwater-Missouri	(182,560.97)	76,269.06		76,269.06	258,830.03	
Cataract	246,965.61					246,965.61
Charlo	12,586,76	17,087.80		17,087.80	4,501.04	
Columbus	103,590.81	3,280.68		3,280.68		100,310.13[d]
Cottonwood	42,600.81	43,891.70		43,891.70	1,290.89	
Daly Ditches	334,723.30	334,723.30[e]		334,723.30		
Deadman's Basin	194,347.47	282,618.00	7,714.74	290,332.74	95,985.27	
Delphia-Melstone	1,110,522.86	193,521.95		193,521.95		917,000.91
Flint Creek	217,919.97	75,710.00		75,710.00		142,209.97
Florence Canal	182,195.79	40,544.46	7,400.00	47,944.46		134,251.33
Fred Burr	35,369.26	32,187.50		32,187.50		3,181.76
Frenchman	119,105.95	102,941.25		102,941.25		16,164.70
Hysham	421,761.13	310,098.37	27,521.43	337,619.80		84,141.33[d]
Lewistown Ditch	1,624.73	1,630.89		1,630.89	6.16	
Little Dry	37,030.00		37,030.00	37,030.00		
Livingston Ditch	(13,323.55)	5,609.00		5,609.00	18,837.55	
Middle Creek	(30,556.89)	101,020.85		101,020.85	131,577.74	
Nevada Creek	102,651.69	66,953.25		66,953.25		35,698.44
Nevada North Canal	130,694.37	3,600.00		3,600.00		127,094.37
Nilan	318,503.07	342,999.00		342,999.00	24,495.93	
No. Fork of Smith River	(98,899.32)				98,899.32	
Painted Rocks	163,496.69					163,496.69
Paradise Canal	262,011.52	222,180.00		222,180.00		39,831.52
Park Branch	20,641.38	37,565.00		37,565.00	16,923.62	
Petrolia	430,699.46	232,802.00	32,510.33	265,312.33		165,387.13[d]
Rock Creek	(57,709.82)	196,655.00	4,148.50	200,803.50	258,513.32	
Ruby River	(34,859.70)	48,620.00		48,620.00	83,479.70	
Sidney	381,324.29		336,609.41	336,609.41		44,714.88[d]
South Side Canal[f]	16,481.97	18,000.00		18,000.00	1,518.03	
Tongue River	(37,719.19)[g]	765,534.73[h]	12,341.00	777,875.73	815,594.92	
Upper Musselshell	205,246.58	240,952.00		240,952.00	35,705.42	
Vigilante Canal	248,981.76	115,342.50		115,342.50		133,639.26
Warhorse	2,603.06					2,603.06
West Bench Canal	47,664.27	42,168.00		42,168.00		5,496.27
Willow Creek	39,291.32	24,011.25		24,011.25		15,280.07
Yellowater	(10,008.24)	8,400.00		8,400.00	18,408.24	2
Total	5,026,511.57	3,982,621.54	468,354.99	4,450,976.53	1,864,667.18	2,430,702.22

[a]The outstanding investment is the state's total investment less the total revenue received as of June 30, 1976. Source: "Detail Project Ledger" on file with the Centralized Services Division, Department of Natural Resources and Conservation.

[b]Source: "Water Purchase Contract Ledger" on file with the Centralized Services Division.

[c]Source: "Repayment Contract Ledger" on file with the Centralized Services Division.

[d]A new contract is being negotiated.

[e]The outstanding investment as of 6/30/76, assumed to be fully repaid. However, a lawsuit was filed in District Court by one of the water users opposing the increased water rate necessary to recover the full outstanding debt. Full recovery of the outstanding investment will depend upon the court ruling.

[f]In accordance with a SWCB decision of 12/6/63, $10,586.15 was credited to the project. Department legal expenses of $2,380.30 incurred in assisting the South Side Water Users Association defend itself against a lawsuit were not charged to the Association.

[g]The cost of the feasibility study on the Tongue River conducted by Bechtel Corporation was not included.

[h]Does not include a contract with Montana Power Company for 4,175 acre-feet.

The following excerpt was taken directly from Water Resources Survey, Gallatin County (January 1953):

MIDDLE CREEK STORAGE PROJECT (S.W.C.B.)

"In order to supplement the water supply for irrigation in Gallatin Valley the State Water Conservation Board received a loan and grant offer from the Federal Government in 1938 to construct the Middle Creek Storage Project. About the same time the Board filed an appropriation dated July 12, 1938, on all the unappropriated water from Middle Creek (also called Hyalite Creek) and its tributaries. The loan and grant offer required the formation of the Middle Creek Water Users' Association as an agency for the distribution of water, to accumulate funds to amortize the cost of the project, and to execute a Water Marketing Contract with the State Water Conservation Board.

The Middle Creek Water Users' Association was incorporated on January 3, 1939, with a capital stock valued at $10,000 divided into 10,000 shares at $1.00 per share. Water Purchase Contracts in the amount of 8,605[1/] acre feet were secured and approved by the Association on June 9, 1939. The original list was comprised of 108 water purchase contracts with the cost of water established at $1.96 per acre foot. In addition to the cost of the water, operation and maintenance charges were set at 26 cents per acre foot.

Bids for construction of the project were received on May 26, 1939, and work was started on the dam July 15, 1939. The dam is located on Middle or Hyalite Creek in Section 15, Township 4 South, Range 6 East, approximately 15 miles

1/ Presently, 7810 acre feet of water storage is contracted.

south of Bozeman. It is an earth, gravel and rock fill structure, 1,310 feet in length, 110 feet high, and floods an area of 248 acres with a total storage capacity of 8,027 acre feet. Above the reservoir is a 27 square mile drainage area, located in a good snow belt, high on the timbered slopes of the Gallatin Range.

Under the same project a diversion canal from Middle Creek to Cottonwood Creek was constructed to transport water to users along Cottonwood Creek. The Cottonwood diversion canal is 3-1/2 miles long and has a carrying capacity of 77 second feet.

This project was scheduled for completion in 1942 but due to shortages of labor, materials, and increased construction costs during and after World War II, it was not ready for operation until the fall of 1950. The first stored water delivered to water users was the season of 1951.

Supplemental water from the reservoir is supplied to users in the Farmers Canal, Hoy Ditch, Middle Creek Ditch, West Gallatin Canal (Kleinschmidt) and to various private ditches."

Financial Status of MCWUA

Present O&M assessments (1984) are $0.90/AF. By 1988 (year of first payment) assessments are projected to be $1.00/AF. By 1988 all but 130 AF of principal will be paid on the existing debt, leaving $765 to be paid. Final payment will be made in 1995 on the last contract signed. The principal payment is $1.96/AF on the existing debt.

The financial statements of the MCWUA for the last three years are presented on the following pages.

Table II.2

Middle Creek Water Users' Association

FINANCIAL STATEMENT

November 1, 1982 - October 31, 1983

BALANCE: November 1, 1982			$2,068.68
INCOME:			
Receipts 3054-3164			
Principal	$6,977.60		
O & M	7,029.00		
Interest (St. share)	7.84		
" Assoc.	4.05		
City (winter water)	2,594.74		
TOTAL		$16,613.23	
			$18,681.95
DISBURSEMENTS			
Checks #1131-1234			
Mt. Dept. Natural Resources	$6,985.44		
Salary, dam tender	2,587.01		
Secretary	653.10		
Repairs - materials	886.48		
Labor	2,746.00		
Office expense	149.80		
Social Security	215.74		
St. Comp. Ins. Fund	161.56		
Liability Insurance	456.00		
Water Commissioner--Farmers	225.00		
Middle Creek	568.89		
Miscellaneous	81.25		
TOTAL		$15,716.27	$15,716.27
BALANCE			$ 2,965.68
CHECK BOOK & BANK BALANCE			$ 2,965.68
INVESTMENTS			
Insured Money Market Fund #91-916-7		$17,106.37	
C. D. #41054		4,041.61	
TOTAL			$21,147.98
TOTAL AVAILABLE			$24,113.66

Table II.3

MIDDLE CREEK WATER USERS' ASSOCIATION

FINANCIAL STATEMENT
November 1, 1981-October 31, 1982

BALANCE: November 1, 1981		$574.85	574.85
INCOME:			
Receipts # 2940-3053			
Principal		$8,790.60	
O & M		6,248.00	
Misc. (Portion ofCD #47034		3,400.00	
Interest. St.		48.51	
" Aseoc.		30.71	
City - Winter Water		1,605.00	
TOTAL			$20,122.82
			$20,697.67
DISBURSEMENTS			
Checks #1098-1131			
Mt. Dept. Natural Resources	$8,839.11		
Salary, dam tender	2,693.13		
Secretary	653.10		
Repairs- materials	3,506.97		
Labor	947.50		
Equipment purchase	570.00		
Office expenses	180.74		
Social Security	226.77		
St. Comp. Insurance	55.67		
Liability Insurance	466.00		
Water Commission '81 & '82	450.00		
Miscellaneous	40.00		
		$18,628.99	$18,628.99
BALANCE			2,068.68
Checkbook & Bank Balance			2,068.68
INVESTMENTS			
CD #41054 on deposit at 1st Security Bank (interest earned $305.81)		$3,587.77	
CD #47034 mature 10/14/82	$19,157.34		
Deposited in Checking Acct.	3,400.00		
Deposited in Savings Acct #5007178		$15,757.34	
			$19,345.11
TOTAL AVAILABLE			[redacted] 21,413.79

Table II.4

MIDDLE CREEK WATER USERS' ASSOCIATION

FINANCIAL STATEMENT

November 1, 1980-October 31, 1981

BALANCE:	November 1, 1980		#3,738.23	$3,738.23
INCOME:				
Receipts #3838-2939				
Principal			$12,896.80	
O & M			6,248.00	
Misc. (Interest C.D. #34991	$1165.77		3,016.82	
				$22,161.62
TOTAL				$25,899.85
DISBURSEMENTS				
Checks #1098-1131				
Mt. Dept. Natural Resources			$12,896.80	
Salary, dam tender			2,849.83	
Secretary			583.44	
Materials			489.19	
Labor (Cottonwood Canal)			3,451.80	
Insurance (Liability)			425.00	
Office expenses			135.97	
Investment Bond			3,000.00	
Social Security			209.03	
St. Comp. Insurance			105.17	
Water Commissioner			1,153.77	
Miscellaneous			25.00	
			$25,325.00	$25,325.00
Balance				574.85
Checkbook Balance		10/31/81		574.85
INVESTMENTS				
Certificate of Deposit #41054 on deposit at 1st Security Bank				
earned interest	$184.39	$3,184.89	3,184.89	
Certificate of Deposit #39307 1st Security		16,824.64	$16,824.64	
			$20,009.53	$20,009.53
TOTAL AVAILABLE				$20,584.38

CHAPTER III
LANDS

LAND CLASSIFICATION

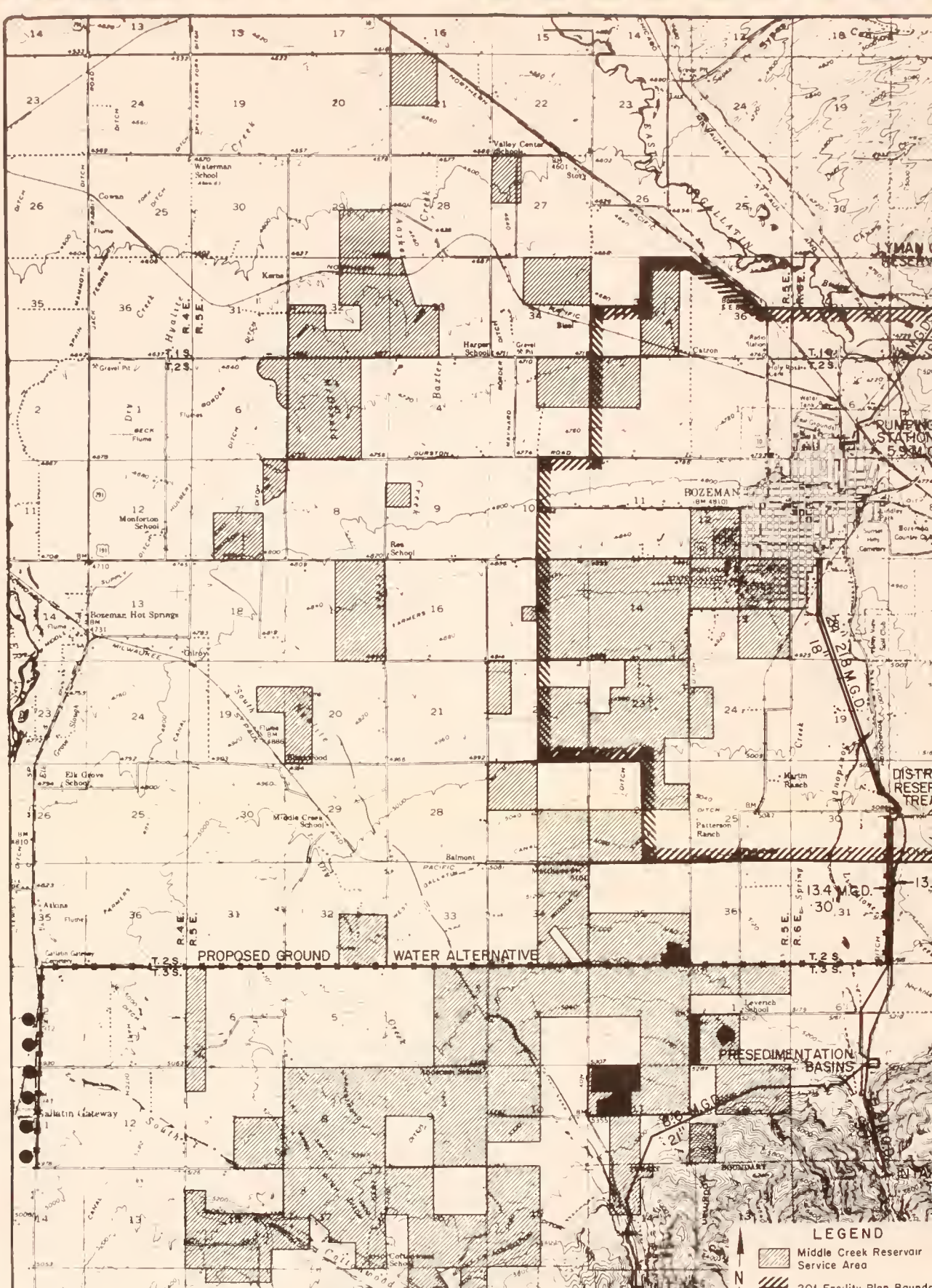
Lands receiving supplemental water have been successfully irrigated for over 35 years. Lands within the valley have been irrigated for nearly 100 years. This valley has naturally occurring fertile soils which have produced some of the best crops in Montana. Because of this demonstrated capability, a land classification program was not considered necessary.

SERVICE AREA

Water is delivered from Hyalite Reservoir (Middle Creek Dam) as a supplemental supply for commercial irrigation, for the municipal (M & I) needs of the City of Bozeman and to small agricultural tracts. Storage water is not tied to a specific place of use as are direct flow rights. For this reason it is difficult to determine a service area as the area is constantly changing. The present service area as shown in Figure III.1 was determined by matching land ownership to contract holders and assuming that storage water would be applied somewhere within this ownership. The service area was determined to be 14,912 acres in size by this method.

As identified in Chapter VIII, Project Evaluation, approximately 60% of a typical farm is irrigated with the rest being dry land farmed or dedicated to homesteads, roads, etc. Assuming this relationship to be applicable to the entire service area 8,950 acres would be irrigated by both direct flow and storage rights. Of this area, it is estimated that only 5,000 acres actually receive storage water in any one year.

As shown in Chapter IX, Financial Program, additional storage water not needed for M & I purposes will be made available on a year to year basis for agricultural use. Existing contract



MIDDLE CREEK DAM REHABILITATION

MIDDLE CREEK RESERVOIR SERVICE AREA

8M087.113

SEPTEMBER 1984

FIGURE II

HKM ASSOCIA
ENGINEERS-PLAN

holders should be given first priority for contracting this water. However, it is likely that other users outside the present service area would also purchase short-term contracts. As identified in Table III.1, acreage irrigated within the Middle Creek drainage is estimated to be 24,819 acres. Thus, there exists potential for supplemental irrigation water contracts. Only those irrigators with the earliest rights would not need additional late season water supplies.

It should be noted that the area identified for water right claims by DNRC is substantially larger than the service area identified in this study. This is justified because of the dynamic nature of the delivery of the water. The water rights map should not be compared to the service area map as they serve two entirely different purposes.

In summary, the service area is dynamic but encompasses less than 15,000 acres, of which storage water is delivered to 5,000 acres. There are approximately 10,000 acres of land outside the service area that could receive supplemental storage water from Hyalite Reservoir. New delivery facilities may be required to deliver this water to the Bozeman Creek Area.

CROPPING PATTERNS AND YIELDS

Since production records are not kept specific to the irrigated acreage of the Middle Creek Water Users Association, it is difficult to develop cropping patterns and yields information. Thus, Gallatin County statistics as developed by the Montana Department of Agriculture and Statistical Reporting Service, (USDA) are adopted. These values should adequately represent the area irrigated and are summarized in Table VIII.1 (See Chapter VIII.) Yields are representative of the increased water supply made available by this project.

TABLE III.1
Acreage Served By Hyalite Creek
Direct Flow and Storage

Reach River Mile Index	Description	Acreage Group #	Direct Flow: Acreage Served By Direct Flow (Acres)	Direct Flow: Service Area Middle Creek Storage (Acres)	Storage Contracts: Ownership Identified (Acre-Feet)	Storage Contracts: Allocation of Unidentified Owner's (Acre-Feet)	Storage Contracts: Total (Acre-Feet)
28.9	Middle Creek Dam						
20.5	City of Bozeman				2,805	0	2,805
	Right Bank Diversions above Hoy Ditch	7	1,383		715		
19.5	Hoy Ditch	6	1,762		485		
17.0	Middle Creek Ditch	5	5,077		1,050		
20.5	Cottonwood Canal + other East Bank diversions	4	2,022		1,445		
			10,244	11,328	3,695	185	3,880
	Diversions, private, between Middle Creek Dam and Farmers Canal	3	1,019		50		
12.6	Farmers Canal	2	12,677		898		
			13,696	3,437	948	52	1,000
	Below Farmers Canal Diversion	1	879	147	120	5	125
	GRAND TOTALS		24,819	14,912			7,810

LAND OWNERSHIP

Two types of land, which are serviced by irrigation water, must bear interest under a Small Reclamation Project Act loan. Those lands that exceed 960 acres in size under ownership of a family unit are called "excess" lands. The excess allocation of the loan must be repaid with interest. The second type of land which bears interest is small agricultural tracts and suburban lands.

Most of the lands utilizing storage water for supplemental irrigation are held in private ownership. Approximately 600 acres of the lands are state owned in the name of Montana State University. It is estimated that 20 acres are held by Gallatin County. All of these lands are supporting commercial agriculture at this time. Analysis of land ownership maps would indicate that no excess lands are held within the service area at this time.

M & I USE

In December of 1984, 2,805 AF of water was held in the name of the City of Bozeman. This portion of Hyalite Reservoir storage is considered M & I water. The 2,805 AF does not include 50 AF of storage right attached to the pending Litchenburg Land and Cattle water right transfer to the City of Bozeman. Should the city successfully complete this transfer, the total storage would increase to 2,855 AF.

Since the irrigation allocation of land repayment does not bear interest under the Small Reclamation Projects Act, it is important to distinguish between commercial farm operations and small agricultural tracts and suburban lands.

The criteria to be followed by the applicant in defining a commercial farm operation is based on a 2-acre minimum limit on tract size and a gross annual sales value approach for tracts between 2 and 10 acres. Water provided to owners of small tracts between 2 and 10 acres that would produce less than $5,000 of gross annual sales of agricultural commodities must be treated as M&I service.

To determine minimum tract size, alfalfa is considered the highest value crop, producing a gross of $227.50/acre (see Chapter VIII, Project Evaluation). Thus, 10 acres would gross $2,275.00 which is less than the $5,000 limit. All tract sizes less than 10 acres which receive storage water would bear interest in loan repayment.

Tracts of 10 acres or less were estimated by superimposing the service area map over large scale aerial photos. Homes and yard boundaries could be identified on these maps in areas obviously subdivided. In this manner, 177 acres were identified with a tract size ranging from 5.5 to 1.95 acres. Storage contracts relating to these lands total 330 AF but include areas which have not been developed into home sites. It is estimated that 1 AF/acre or 177 AF are actually released from storage for these tracts. It should be noted that this calculation was made for purposes of the financial analysis. Actual acreage falling into the "small tract" category will be calculated each year and appropriate adjustments made in the loan repayment.

In summary, 2,980 AF are presently eligible for M & I allocation. This value is rounded to 3,000 AF in the cost allocation in Chapter IX, Financial Program. It is assumed that the City of Bozeman will not need additional water in year 1 of the payout schedule, as permanent provisions for wintertime releases would solve most of the present water

supply problems (See Chapter VIII, Project Evaluation). The additional 2334 AF of storage water would be used by agriculture on a temporary basis and held for the city as needed. At or before the expiration of the 40-year loan term, all of this water would likely be committed to M & I use.

CHAPTER IV
WATER

WATER REQUIREMENTS

Monthly farm delivery requirements and diversion requirements were developed using both records and calculated consumptive use requirements. Consumptive use and effective precipitation were calculated using the Blaney-Criddle Method, SCS TR-21 version, for alfalfa and barley using Bozeman, Montana climatic data. Precipitation for Bozeman is shown in Table IV.1. Summary tables for consumptive use are provided in Tables IV.2 and IV.3. Detailed printouts of consumptive use can be referenced in the files.

Net irrigation requirements were calculated by subtracting effective rainfall from consumptive use. See Tables IV.4 and IV.5 for effective precipitation for alfalfa and barley respectively. A weighted net irrigation requirement was obtained using a cropping pattern of 62.5% alfalfa and 37.5% barley (see Table IV.6).

The following paragraphs, as paraphrased from TR-21, summarize the Blaney-Criddle Technique. This process has been computerized by HKM Associates for ease of calculations.

Early in the 1900's researchers found that the amount of water consumptively used by vegetation during their normal growing season was closely related to mean monthly temperatures and daylight hours. Mr. Harry Blaney and Mr. Wayne Criddle developed equations that could be used to transpose the consumptive use data for a given area to other areas for which

only climatological data are available. The net amount of irrigation water necessary to satisfy consumptive use is found by subtracting the effective precipitation from the consumptive water requirement.

Numerous climatic factors must be taken into consideration if the net consumptive use of water is to be determined accurately. Of the climatic factors, the effect of temperature, hours of sunshine available for plant growth and effective precipitation are the most important. Other influencing factors, not directly considered by the Blaney-Criddle equation, are:

1. Actual radiation energy received by the plant.

2. Relative humidity.

3. Wind speed.

4. Altitude.

5. Advection.

6. Soil Factors.

7. Plant Factors.

The general effect of varying seasonal radiation can be introduced by computing the length of sunshine during the growing season at various latitudes. As an example, the length of the daytime at the Equator varies little throughout the year, whereas at 50°N. latitude, the length of the day in summer is much longer than in winter. Thus, at equal

temperatures, photosynthesis can take place for several hours longer each June day at the north latitude than at the Equator. Growth and water consumption vary with the opportunity for photosynthesis.

The Blaney/Criddle Formula

Disregarding many other influencing factors, consumptive use primarily varies with the temperature, length of day, and available moisture regardless of its source (precipitation, irrigation water, or natural ground water). Multiplying the mean monthly temperature (t) by the possible monthly percentage of daytime hours of the year (p) gives a monthly consumptive-use factor (f). It is assumed that crop consumptive use varies directly with this factor when an ample water supply is available. Expressed mathematically:

u = kf, where,

u = Monthly consumptive use of the plants in inches.

k = Empirical consumptive use coefficient for a month

f = Monthly consumptive use factor (product of mean monthly temperature and monthly percentage of daylight hours of the year).

f = t x p, where

t = Mean monthly air temperature in degrees Fahrenheit

p = Monthly percentage of daylight hours in the year. Values of (p) for latitudes 0 to 65 degrees north of the Equator can be found in Tables in TR-21.

And:

U = KF = sum of kf, where,

U = Consumptive use in inches for the growing season

K = Empirical consumptive use coefficient for the growing season. This coefficient varies with the different vegetation being considered.

F = Sum of the monthly consumptive use factors for the growing season (sum of the products of mean monthly temperature and monthly percentage of daylight hours of the year).

Note: Values of (t), (p), (f), and (k), can also be made to apply to shorter periods. However, we have found the formula to be most accurate on a seasonal basis.

Following are modifications made to the original formula by the SCS:

k = k_t x k_c, where,

k_t = A climatic coefficient which is related to the mean air temperature (t). Values of k_t for mean air temperatures from 36 to 100 degrees are shown in Table 4 in TR-21.

k_c = A coefficient reflecting the growth stage of the plants. Values are obtained from growth stage coefficient curves given in TR-21 or developed by HKM Associates.

The consumptive use factor (F) may be computed for areas for which monthly temperature records are available. Then, the total crop consumptive use (U) is obtained my multiplying (F) by the empirical consumptive use crop coefficient (K). This relationship allows the computation of seasonal consumptive use at any location for those plants for which values of (K) have been experimentally established or can be estimated.

Growing Season

In utilizing the Blaney-Criddle formula for computing seasonal requirements, the potential growing season for the various species is normally considered to extend from killing frost to killing frost or from the last killing frost in the spring to

the end of a definite period of time thereafter. For most crops, this is adequate for seasonal use estimates, but a refinement is necessary to more precisely define the growing season when monthly or short-time use estimates are required. In many areas, records are available from which planting, harvesting and growth dates can be determined. These should be used where possible. In other areas, temperature data may be helpful for estimating these dates. Table IV.1 contains some guides which are helpful in determining these dates.

Since the spring frost date corresponds very nearly with a mean temperature of 55 degrees, it is obvious that many of the common plants use appreciable amounts of water prior to the last frost in the spring and may continue to use water after the first frost in the fall. If non-growing season precipitation is significant it may be necessary to analyze the consumptive use for the entire year. Non-growing season soil moisture gains can be used by the plant growth during the growing season reducing irrigation requirements. Non-growing season moisture gains were not considered in this analysis so that irrigation demands would remain conservatively high.

Table IV.1. A Guide for Determining Planting Dates, Maturity Dates and Lengths of Growing Seasons as Related to Mean Air Temperature

Crop	Earliest Moisture use or planting date as related to mean air temperature	Latest Moisture use or maturing date as related to mean air temperature	Growing Season days
Perennial Crops			
Alfalfa	50° mean temp	28° frost	Variable
Grasses, cool	45° mean temp	45° mean temp	Variable
Annual Crops			
Grain, spring	45° mean temp	32° frost	130 - Max.

Source: SCS TR-21

Growth Stage Coefficients

As previously stated, another factor which causes consumptive use to vary widely throughout the growing season is the plant itself. Stage of growth is a primary variable that must be recognized since it is obvious that plants in the higher level of maturity will use water at a more rapid rate than will new seedlings. It is also obvious that these variations in consumptive use throughout the growing season will be greater for annual plants than for perennial plants such as alfalfa, permanent pasture grasses, deciduous trees, willows and others.

In order to recognize these variations in consumptive use, plant growth stage coefficients (k_c) have been introduced into the formula. Values of these coefficients are calculated from research data. When values of (k_c) are plotted against time or stage of growth curves, can be developed. Such curves are used to obtain values of (k_c) which, when used with appropriate values of (k_t), will permit a determination of values of monthly or short-time consumptive use coefficients (k).

It is also recognized that value of (k_c) might, to some extent, be influenced by factors other than the characteristics of the plant itself. For this reason, it is not expected that these curves can be used universally. They should, however, be valid over a considerable area and certainly should be of value in areas where no measured consumptive-use is available. However, coefficients developed and calibrated specifically for the area under consideration will give better results.

Table IV.2

Monthly Precipitation (Historic)

MONTHLY PRECIPITATION (HISTORIC)

FILE -- BOZPREC1
SITE -- BOZEMAN
UNIT -- INCHES
NOTE -- ANY MONTH WITH ****.** INDICATES NO DATA AVAILABLE

10/09/84

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL TOTAL
1931	1.10	1.13	1.37	1.21	2.23	1.50	1.46	.37	2.13	.81	1.19	.79	15.29
1932	1.02	.31	2.25	2.56	.59	3.29	1.55	1.54	.21	2.23	1.13	.56	17.34
1933	.77	.66	.96	1.37	2.56	1.13	.40	3.48	1.87	1.78	.34	.57	15.39
1934	.67	.71	1.33	.19	.88	2.35	.40	.07	1.06	1.47	.32	1.29	10.54
1935	.75	.29	3.24	1.92	2.35	1.76	.77	.70	.15	2.35	.67	.51	15.46
1936	1.19	1.25	.67	.93	1.31	2.13	.09	1.48	1.04	.74	.66	1.29	12.78
1937	1.64	1.15	1.27	2.42	.82	3.90	2.16	.20	2.33	.51	.67	.92	17.39
1938	.38	.44	3.23	1.55	5.63	1.82	1.20	.88	.09	3.10	1.89	.14	20.34
1939	.74	.52	1.02	.99	1.31	3.71	.69	.94	1.29	1.17	.05	1.00	14.03
1940	1.48	1.22	1.28	3.33	1.38	2.99	.61	.45	2.48	1.05	1.25	1.11	18.63
1941	.20	.44	.78	3.50	1.45	3.17	1.26	1.80	4.60	1.17	2.74	1.75	22.36
1942	2.15	1.71	1.48	.79	2.44	2.68	.47	.53	1.54	1.22	1.78	.45	17.24
1943	.88	.32	1.07	3.07	2.10	2.50	1.90	1.24	.91	1.95	.74	.59	17.27
1944	.12	.73	.96	.60	3.00	7.98	1.70	1.42	2.13	.97	.73	.59	20.92
1945	.36	.47	1.15	1.15	3.67	4.10	.76	1.73	1.84	1.15	1.18	1.97	19.53
1946	1.26	1.13	2.36	1.43	3.03	1.33	1.47	.76	1.97	2.35	.85	.59	13.58
1947	.93	.44	3.02	1.38	1.05	6.78	.37	.80	4.58	.69	3.25	1.35	24.53
1948	1.11	.65	.89	2.04	2.37	4.87	1.58	1.91	.60	.52	1.53	1.43	19.50
1949	1.89	.86	1.07	2.06	1.92	3.73	.51	.55	2.21	1.21	.51	.59	17.11
1950	.74	.75	2.00	.99	2.07	2.16	2.74	1.86	1.99	.87	1.10	.92	18.18
1951	.46	.49	1.75	1.84	1.52	1.61	.87	2.36	2.23	4.46	.81	1.80	20.20
1952	1.24	1.19	1.59	1.99	6.63	2.02	1.28	1.16	.56	.21	1.29	.41	19.56
1953	.65	1.05	1.04	2.05	3.23	3.13	.63	.42	1.00	1.39	1.13	.68	16.40
1954	1.10	.13	1.19	.44	1.70	3.70	.66	1.32	1.21	.88	.07	.23	12.68
1955	.54	1.00	1.33	3.51	2.70	2.23	1.55	.12	1.11	2.04	.78	2.16	19.06
1956	.78	.16	1.27	1.66	2.06	1.06	.46	.95	.97	1.12	.52	.29	11.30
1957	.74	.20	1.16	1.27	2.80	4.68	1.52	.70	.85	1.46	.56	.58	16.52
1958	.82	.88	1.52	1.91	.37	2.43	3.25	2.52	1.40	.41	1.69	.91	18.11
1959	.79	1.12	1.58	1.37	4.08	2.42	1.63	.74	2.35	1.93	.90	.67	19.58
1960	.78	.71	1.77	2.32	2.33	1.18	.37	2.14	.43	.88	1.02	.69	14.61
1961	.11	.84	.92	2.49	1.39	.82	.71	.58	4.90	2.11	1.10	.25	16.12
1962	1.27	.49	1.32	1.12	3.86	1.55	3.08	2.14	.64	1.15	3.01	.34	19.97
1963	1.76	.53	1.06	1.98	3.29	3.13	1.09	.80	2.00	.94	.61	.67	17.86
1964	.48	.67	1.19	2.12	3.11	3.72	.91	3.80	.08	1.29	1.57	.91	19.84
1965	.97	.50	.45	2.24	4.16	3.76	.68	2.23	2.42	.45	.75	.61	19.22
1966	.75	.22	1.18	1.10	2.54	2.84	.46	1.26	1.08	1.53	.98	.69	14.63
1967	1.17	.76	3.28	1.45	2.05	4.44	1.12	.27	1.21	3.48	2.09	1.62	22.93
1968	.91	.44	2.13	1.42	4.03	3.78	1.08	2.63	2.77	1.37	2.65	.35	23.55
1969	1.95	.44	.46	2.51	1.92	7.37	1.70	1.50	.86	3.02	.58	1.09	23.40
1970	.70	.32	2.21	1.55	3.42	1.48	3.15	.97	2.23	1.58	1.41	.62	19.63
1971	.96	1.01	.74	2.82	2.20	2.86	.29	.70	2.61	.65	.77	.56	15.97
1972	.86	.66	1.24	1.91	1.73	3.07	1.20	1.44	2.00	2.59	.63	.49	17.32
1973	1.10	.04	1.89	2.84	1.44	4.43	.50	1.63	2.89	1.74	1.27	1.29	21.06
1974	.42	.43	1.71	1.87	3.00	.96	.48	2.65	1.46	1.60	.67	1.02	16.27
1975	1.58	1.11	1.08	1.77	4.88	3.46	1.89	1.13	1.67	4.29	1.33	1.10	25.28
1976	.60	.52	1.03	3.35	1.95	4.00	1.64	.79	3.29	1.77	.20	.22	19.36
1977	.60	.06	2.39	.57	3.84	2.21	2.24	2.13	2.88	1.44	1.19	1.19	20.73
1978	1.03	.87	.76	.93	4.04	2.11	2.17	.82	4.22	.81	1.87	.72	20.34
1979	1.03	.75	.77	1.92	2.33	3.66	.59	1.51	.07	1.54	.96	.30	15.43
1980	1.17	1.29	1.67	.39	5.68	2.85	1.12	1.85	3.40	.73	.77	.31	21.22
1981	.50	1.31	.99	1.99	6.99	3.96	1.14	.50	1.31	2.13	1.13	.75	22.70
1982	1.06	.78	2.80	2.20	2.88	4.04	1.52	1.01	2.92	1.34	.52	1.35	22.42
MEAN	.92	.69	1.47	1.77	2.71	3.05	1.21	1.29	1.80	1.53	1.10	.83	18.42
S.D.	.45	.37	.71	.81	1.43	1.51	.76	.82	1.17	.91	.69	.47	3.28
COEF. VAR.	.489	.538	.481	.456	.528	.495	.632	.639	.653	.595	.633	.571	.178
PERCENT OF ANNUAL MEAN	5.0%	3.8%	8.0%	9.6%	14.7%	16.6%	6.6%	7.0%	9.8%	8.3%	6.0%	4.5%	
SUM OF MONTHLY MEANS													18.4

Table IV.3

Consumptive Use - Alfalfa

CONSUMPTIVE USE ALFALFA

FILE -- COUSAL2
SITE -- BOZEMAN
UNIT -- IN
NOTE -- ANY MONTH WITH ****.** INDICATES NO DATA AVAILABLE 10/09/84

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL TOTAL
1931	0.00	0.00	0.00	0.00	2.94	5.46	6.81	5.79	3.11	.19	0.00	0.00	24.30
1932	0.00	0.00	0.00	0.00	2.34	4.87	6.44	5.36	3.05	.17	0.00	0.00	22.22
1933	0.00	0.00	0.00	0.00	1.18	5.94	7.27	5.01	2.34	.20	0.00	0.00	22.44
1934	0.00	0.00	0.00	1.14	4.56	4.87	6.36	5.95	2.52	.19	0.00	0.00	26.09
1935	0.00	0.00	0.00	0.00	.65	4.55	6.58	5.38	3.34	.19	0.00	0.00	20.68
1936	0.00	0.00	0.00	0.00	4.32	5.46	7.90	5.75	3.05	.19	0.00	0.00	26.67
1937	0.00	0.00	0.00	0.00	2.51	4.55	6.67	5.40	3.30	.22	0.00	0.00	22.65
1938	0.00	0.00	0.00	0.00	1.01	4.99	6.09	5.23	3.95	.22	0.00	0.00	21.49
1939	0.00	0.00	0.00	0.00	3.81	4.01	6.46	5.36	3.05	.19	0.00	0.00	22.37
1940	0.00	0.00	0.00	0.00	3.18	5.37	6.77	5.73	3.33	.22	0.00	0.00	24.59
1941	0.00	0.00	0.00	0.00	2.76	4.87	6.34	5.36	2.21	.15	0.00	0.00	21.68
1942	0.00	0.00	0.00	0.00	0.00	3.95	6.30	5.28	2.95	.19	0.00	0.00	18.67
1943	0.00	0.00	0.00	0.00	.10	4.10	6.07	5.21	3.08	.21	0.00	0.00	19.77
1944	0.00	0.00	0.00	0.00	2.71	4.06	5.67	4.82	3.03	.22	0.00	0.00	20.50
1945	0.00	0.00	0.00	0.00	.32	3.79	6.21	5.44	2.64	.20	0.00	0.00	18.60
1946	0.00	0.00	0.00	0.00	.65	4.71	6.62	5.21	2.89	.15	0.00	0.00	20.22
1947	0.00	0.00	0.00	0.00	3.09	4.12	7.15	5.56	2.88	.21	0.00	0.00	23.00
1948	0.00	0.00	0.00	0.00	2.75	5.24	6.12	5.25	3.33	.40	0.00	0.00	23.09
1949	0.00	0.00	0.00	.36	3.79	4.53	6.60	6.06	1.45	0.00	0.00	0.00	22.79
1950	0.00	0.00	0.00	0.00	.54	4.45	5.63	4.88	3.03	.20	0.00	0.00	18.73
1951	0.00	0.00	0.00	0.00	2.09	3.66	6.44	4.80	2.37	0.00	0.00	0.00	19.36
1952	0.00	0.00	0.00	0.00	2.54	5.20	6.18	5.60	3.40	.44	0.00	0.00	23.36
1953	0.00	0.00	0.00	0.00	.55	4.77	7.08	5.91	3.55	1.42	0.00	0.00	23.27
1954	0.00	0.00	0.00	0.00	2.38	4.29	7.25	5.25	3.11	.06	0.00	0.00	22.34
1955	0.00	0.00	0.00	0.00	1.70	4.57	6.28	6.27	2.98	0.00	0.00	0.00	21.79
1956	0.00	0.00	0.00	0.00	2.44	5.67	6.69	4.95	3.46	1.22	0.00	0.00	24.42
1957	0.00	0.00	0.00	0.00	2.39	4.91	6.55	5.62	2.16	0.00	0.00	0.00	21.63
1958	0.00	0.00	0.00	0.00	4.80	4.95	5.63	5.91	2.99	1.26	0.00	0.00	25.54
1959	0.00	0.00	0.00	0.00	.80	5.48	6.65	5.32	2.67	0.00	0.00	0.00	20.92
1960	0.00	0.00	0.00	0.00	1.62	5.05	7.47	5.30	2.49	0.00	0.00	0.00	21.93
1961	0.00	0.00	0.00	0.00	2.41	6.45	7.27	6.38	1.88	0.00	0.00	0.00	24.39
1962	0.00	0.00	0.00	0.00	1.64	5.14	6.00	5.11	.47	0.00	0.00	0.00	18.36
1963	0.00	0.00	0.00	0.00	2.35	4.85	6.55	5.87	3.89	1.69	0.00	0.00	25.19
1964	0.00	0.00	0.00	0.00	2.05	4.57	7.35	4.99	1.17	0.00	0.00	0.00	20.13
1965	0.00	0.00	0.00	0.00	.77	4.75	6.30	4.99	1.17	0.00	0.00	0.00	17.98
1966	0.00	0.00	0.00	0.00	3.10	4.59	7.20	5.28	3.63	.85	0.00	0.00	24.65
1967	0.00	0.00	0.00	0.00	1.56	4.51	6.81	6.06	3.86	.29	0.00	0.00	23.09
1968	0.00	0.00	0.00	0.00	.77	4.63	6.53	4.58	2.08	0.00	0.00	0.00	18.59
1969	0.00	0.00	0.00	0.00	.09	3.84	4.41	6.34	6.02	3.49	0.00	0.00	24.19
1970	0.00	0.00	0.00	0.00	2.22	5.67	6.91	6.27	1.37	0.00	0.00	0.00	22.43
1971	0.00	0.00	0.00	0.00	2.47	4.79	6.23	6.69	1.87	0.00	0.00	0.00	22.05
1972	0.00	0.00	0.00	0.00	2.02	5.59	5.91	5.93	2.29	0.00	0.00	0.00	21.74
1973	0.00	0.00	0.00	0.00	2.13	5.16	6.86	5.87	2.82	.20	0.00	0.00	23.04
1974	0.00	0.00	0.00	0.00	1.34	6.14	7.40	5.09	3.01	.41	0.00	0.00	23.38
1975	0.00	0.00	0.00	0.00	.44	4.43	7.23	4.92	3.03	1.18	0.00	0.00	21.23
1976	0.00	0.00	0.00	0.00	3.54	4.85	6.91	5.30	3.37	.88	0.00	0.00	24.84
1977	0.00	0.00	0.00	0.00	2.23	5.90	6.32	5.23	3.04	.63	0.00	0.00	23.35
1978	0.00	0.00	0.00	0.00	1.62	5.12	6.37	5.40	3.32	.86	0.00	0.00	22.68
1979	0.00	0.00	0.00	0.00	2.27	5.37	6.89	5.73	4.01	.69	0.00	0.00	24.95
1980	0.00	0.00	0.00	0.00	3.74	5.16	6.65	4.94	3.19	.96	0.00	0.00	24.63
1981	0.00	0.00	0.00	0.00	2.15	4.67	6.67	6.29	3.53	.32	0.00	0.00	23.62
1982	0.00	0.00	0.00	0.00	1.13	4.93	6.60	6.04	2.89	.48	0.00	0.00	22.06
MEAN	0.00	0.00	0.00	.02	2.04	4.87	6.57	5.50	2.88	.40	0.00	0.00	22.33
S.D.	0.00	0.00	0.00	.16	1.18	.60	.57	.48	.86	.60	0.00	0.00	2.15
COEF. VAR.	+***.***	+***.***	+***.***	5.714	.580	.125	.087	.087	.301	1.476	+***.***	+***.***	.096
PERCENT OF ANNUAL MEAN	0.0%	0.0%	0.0%	.1%	9.2%	21.8%	29.5%	24.6%	12.9%	1.8%	0.0%	0.0%	
SUM OF MONTHLY MEANS													22.3

Table IV.4

Consumptive Use - Barley

CONSUMPTIVE USE BARLEY

FILE -- COUSBA2
SITE -- BOZEMAN
UNIT -- INCHES
NOTE -- ANY MONTH WITH ####.## INDICATES NO DATA AVAILABLE

10/09/84

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL TOTAL
1931	0.00	0.00	0.00	.16	2.18	5.60	7.29	1.99	0.00	0.00	0.00	0.00	17.22
1932	0.00	0.00	0.00	.13	1.97	4.92	6.97	1.99	0.00	0.00	0.00	0.00	15.98
1933	0.00	0.00	0.00	0.00	.92	4.81	3.59	3.78	.22	0.00	0.00	0.00	13.32
1934	0.00	0.00	0.00	1.07	4.18	5.49	4.23	.20	0.00	0.00	0.00	0.00	15.17
1935	0.00	0.00	0.00	0.00	.78	3.55	7.77	4.33	.35	0.00	0.00	0.00	16.78
1936	0.00	0.00	0.00	.22	2.73	5.76	8.18	1.66	0.00	0.00	0.00	0.00	18.54
1937	0.00	0.00	0.00	0.00	1.71	4.21	7.56	2.90	.05	0.00	0.00	0.00	16.43
1938	0.00	0.00	0.00	0.00	1.17	4.40	7.01	3.23	.14	0.00	0.00	0.00	15.95
1939	0.00	0.00	0.00	.45	2.84	4.57	5.74	.90	0.00	0.00	0.00	0.00	14.50
1940	0.00	0.00	0.00	.13	2.27	5.43	7.33	2.13	0.00	0.00	0.00	0.00	17.29
1941	0.00	0.00	0.00	.13	2.09	4.92	6.87	1.99	0.00	0.00	0.00	0.00	16.00
1942	0.00	0.00	0.00	0.00	1.24	3.66	7.14	2.83	.05	0.00	0.00	0.00	14.92
1943	0.00	0.00	0.00	.62	1.91	4.67	5.40	.87	0.00	0.00	0.00	0.00	13.27
1944	0.00	0.00	0.00	.29	2.40	4.44	5.54	1.17	0.00	0.00	0.00	0.00	13.86
1945	0.00	0.00	0.00	0.00	.87	3.07	7.33	4.10	.21	0.00	0.00	0.00	15.58
1946	0.00	0.00	0.00	.65	2.18	5.42	5.08	.47	0.00	0.00	0.00	0.00	13.30
1947	0.00	0.00	0.00	.18	2.34	4.29	7.54	1.78	0.00	0.00	0.00	0.00	16.13
1948	0.00	0.00	0.00	.23	2.27	5.61	6.21	1.45	0.00	0.00	0.00	0.00	15.77
1949	0.00	0.00	0.00	.62	3.01	5.21	5.39	.66	0.00	0.00	0.00	0.00	14.89
1950	0.00	0.00	0.00	0.00	.97	3.73	6.65	3.42	.17	0.00	0.00	0.00	14.94
1951	0.00	0.00	0.00	.06	1.78	3.55	7.19	2.18	.02	0.00	0.00	0.00	14.78
1952	0.00	0.00	0.00	.44	2.46	5.92	5.50	.93	0.00	0.00	0.00	0.00	15.25
1953	0.00	0.00	0.00	0.00	.70	3.65	8.36	4.90	.44	0.00	0.00	0.00	18.05
1954	0.00	0.00	0.00	.23	2.19	4.59	7.36	1.48	0.00	0.00	0.00	0.00	15.35
1955	0.00	0.00	0.00	0.00	1.99	3.89	.01	0.00	0.00	0.00	0.00	0.00	5.89
1956	0.00	0.00	0.00	.06	1.82	5.53	7.45	2.13	.01	0.00	0.00	0.00	17.00
1957	0.00	0.00	0.00	.04	1.78	4.68	7.35	2.71	.02	0.00	0.00	0.00	16.58
1958	0.00	0.00	0.00	.17	2.86	5.08	6.02	2.03	0.00	0.00	0.00	0.00	16.16
1959	0.00	0.00	0.00	0.00	.89	4.58	7.78	3.32	.08	0.00	0.00	0.00	16.65
1960	0.00	0.00	0.00	0.00	1.53	4.96	8.05	1.69	0.00	0.00	0.00	0.00	16.23
1961	0.00	0.00	0.00	.02	1.68	6.06	8.20	3.24	.04	0.00	0.00	0.00	19.24
1962	0.00	0.00	0.00	.43	2.32	5.85	5.34	.85	0.00	0.00	0.00	0.00	14.79
1963	0.00	0.00	0.00	.08	1.86	4.76	7.26	2.50	.01	0.00	0.00	0.00	16.47
1964	0.00	0.00	0.00	0.00	1.63	4.45	7.98	1.63	0.00	0.00	0.00	0.00	15.69
1965	0.00	0.00	0.00	0.00	1.34	4.60	4.91	1.67	0.00	0.00	0.00	0.00	12.52
1966	0.00	0.00	0.00	.08	2.14	4.51	7.98	2.25	.01	0.00	0.00	0.00	16.97
1967	0.00	0.00	0.00	0.00	1.18	3.91	7.32	3.92	.15	0.00	0.00	0.00	17.08
1968	0.00	0.00	0.00	0.00	.96	4.06	7.42	2.16	.01	0.00	0.00	0.00	14.61
1969	0.00	0.00	0.00	.47	2.87	5.02	5.64	.99	0.00	0.00	0.00	0.00	14.99
1970	0.00	0.00	0.00	0.00	1.32	4.92	3.03	4.05	.12	0.00	0.00	0.00	18.43
1971	0.00	0.00	0.00	.06	1.83	4.64	6.96	3.03	.02	0.00	0.00	0.00	16.54
1972	0.00	0.00	0.00	.04	1.64	5.33	6.64	2.85	.02	0.00	0.00	0.00	16.52
1973	0.00	0.00	0.00	0.00	1.52	4.70	7.81	3.31	.07	0.00	0.00	0.00	17.41
1974	0.00	0.00	0.00	.42	2.12	7.00	6.58	.88	0.00	0.00	0.00	0.00	17.00
1975	0.00	0.00	0.00	0.00	.67	3.32	8.53	4.20	.39	0.00	0.00	0.00	17.11
1976	0.00	0.00	0.00	.24	2.62	5.18	7.01	1.49	0.00	0.00	0.00	0.00	16.54
1977	0.00	0.00	0.00	.59	2.50	6.79	5.16	.58	0.00	0.00	0.00	0.00	15.62
1978	0.00	0.00	0.00	.32	2.14	5.67	6.09	1.14	0.00	0.00	0.00	0.00	15.36
1979	0.00	0.00	0.00	.10	1.88	5.36	7.54	2.28	.01	0.00	0.00	0.00	17.17
1980	0.00	0.00	0.00	.54	2.91	5.92	5.59	.68	0.00	0.00	0.00	0.00	15.64
1981	0.00	0.00	0.00	.35	2.33	5.22	6.25	1.25	0.00	0.00	0.00	0.00	15.40
1982	0.00	0.00	0.00	0.00	1.03	4.13	7.79	4.23	.18	0.00	0.00	0.00	17.36
MEAN	0.00	0.00	0.00	.18	1.89	4.83	6.75	2.16	.05	0.00	0.00	0.00	15.38
S.D.	0.00	0.00	0.00	.23	.71	.84	1.43	1.22	.10	0.00	0.00	0.00	1.94
COEF. VAR.	+###.###	+###.###	+###.###	1.278	.377	.173	.212	.565	1.933	+###.###	+###.###	+###.###	.122
PERCENT OF ANNUAL MEAN	0.0%	0.0%	0.0%	1.1%	11.9%	30.5%	42.5%	13.6%	.3%	0.0%	0.0%	0.0%	
SUM OF MONTHLY MEANS													15.9

Table IV.5

Effective Precipitation - Barley

EFFECTIVE PRECIP. BARLEY

FILE -- EFPREC82
SITE -- BOZEMAN
UNIT -- IN
NOTE -- ANY MONTH WITH ****.** INDICATES NO DATA AVAILABLE 10/09/84

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL TOTAL
1931	0.00	0.00	0.00	.28	2.23	1.50	1.46	.37	0.00	0.00	0.00	0.00	5.84
1932	0.00	0.00	0.00	.51	.69	3.29	1.55	1.54	0.00	0.00	0.00	0.00	7.58
1933	0.00	0.00	0.00	0.00	1.90	1.13	.40	3.48	.34	0.00	0.00	0.00	7.85
1934	0.00	0.00	0.00	.17	.88	2.35	.40	0.00	0.00	0.00	0.00	0.00	3.80
1935	0.00	0.00	0.00	0.00	1.59	1.76	.77	.70	0.00	0.00	0.00	0.00	4.82
1936	0.00	0.00	0.00	.28	1.31	2.13	0.00	1.38	0.00	0.00	0.00	0.00	5.10
1937	0.00	0.00	0.00	0.00	.82	3.90	2.16	.20	.54	0.00	0.00	0.00	7.61
1938	0.00	0.00	0.00	0.00	5.09	1.82	1.20	.88	0.00	0.00	0.00	0.00	8.99
1939	0.00	0.00	0.00	.53	1.91	3.71	.69	.67	0.00	0.00	0.00	0.00	7.51
1940	0.00	0.00	0.00	.67	1.38	2.99	.61	.45	0.00	0.00	0.00	0.00	6.10
1941	0.00	0.00	0.00	.70	1.45	3.17	1.26	1.80	.15	0.00	0.00	0.00	8.53
1942	0.00	0.00	0.00	0.00	2.44	2.68	.47	.53	.36	0.00	0.00	0.00	6.48
1943	0.00	0.00	0.00	1.64	2.10	2.50	1.90	.88	0.00	0.00	0.00	0.00	9.02
1944	0.00	0.00	0.00	.24	3.00	7.98	1.70	1.19	0.00	0.00	0.00	0.00	14.11
1945	0.00	0.00	0.00	0.00	2.72	4.10	.76	1.73	.92	0.00	0.00	0.00	10.23
1946	0.00	0.00	0.00	1.00	3.03	1.38	1.47	.42	0.00	0.00	0.00	0.00	7.30
1947	0.00	0.00	0.00	.37	1.05	6.78	.37	.77	0.00	0.00	0.00	0.00	9.34
1948	0.00	0.00	0.00	.68	2.37	4.87	1.58	1.73	0.00	0.00	0.00	0.00	11.23
1949	0.00	0.00	0.00	1.30	1.92	3.73	.51	.34	0.00	0.00	0.00	0.00	7.80
1950	0.00	0.00	0.00	0.00	1.67	2.16	2.74	1.86	.86	0.00	0.00	0.00	9.29
1951	0.00	0.00	0.00	.18	1.52	1.61	.87	2.36	.30	0.00	0.00	0.00	6.84
1952	0.00	0.00	0.00	1.06	6.63	2.02	1.28	.82	0.00	0.00	0.00	0.00	11.81
1953	0.00	0.00	0.00	0.00	2.08	3.13	.63	.42	.60	0.00	0.00	0.00	6.86
1954	0.00	0.00	0.00	.15	1.70	3.70	.66	1.19	0.00	0.00	0.00	0.00	7.40
1955	0.00	0.00	0.00	0.00	2.35	2.23	0.00	0.00	0.00	0.00	0.00	0.00	4.58
1956	0.00	0.00	0.00	.17	2.06	1.06	.46	.95	0.00	0.00	0.00	0.00	4.70
1957	0.00	0.00	0.00	0.00	2.80	4.68	1.52	.70	.14	0.00	0.00	0.00	9.84
1958	0.00	0.00	0.00	.45	.37	2.43	3.25	2.52	0.00	0.00	0.00	0.00	9.02
1959	0.00	0.00	0.00	0.00	3.03	2.42	1.63	.74	.71	0.00	0.00	0.00	8.53
1960	0.00	0.00	0.00	0.00	2.33	1.18	.37	1.93	0.00	0.00	0.00	0.00	5.81
1961	0.00	0.00	0.00	0.00	1.39	.82	.71	.58	.18	0.00	0.00	0.00	3.68
1962	0.00	0.00	0.00	.60	3.86	1.55	3.08	1.52	0.00	0.00	0.00	0.00	10.61
1963	0.00	0.00	0.00	.26	3.29	3.13	1.09	.80	.20	0.00	0.00	0.00	8.77
1964	0.00	0.00	0.00	0.00	3.11	3.72	.91	3.55	0.00	0.00	0.00	0.00	11.29
1965	0.00	0.00	0.00	0.00	4.16	3.76	.68	2.16	0.00	0.00	0.00	0.00	10.76
1966	0.00	0.00	0.00	.15	2.54	2.84	.46	1.26	0.00	0.00	0.00	0.00	7.25
1967	0.00	0.00	0.00	0.00	1.79	4.44	1.12	.27	.44	0.00	0.00	0.00	8.06
1968	0.00	0.00	0.00	0.00	3.12	3.78	1.08	2.63	.28	0.00	0.00	0.00	10.39
1969	0.00	0.00	0.00	1.34	1.92	7.37	1.70	1.06	0.00	0.00	0.00	0.00	13.39
1970	0.00	0.00	0.00	0.00	2.98	1.48	3.15	.97	.82	0.00	0.00	0.00	9.40
1971	0.00	0.00	0.00	.28	2.20	2.86	.29	.70	.32	0.00	0.00	0.00	6.65
1972	0.00	0.00	0.00	.13	1.73	3.07	1.20	1.44	.33	0.00	0.00	0.00	7.90
1973	0.00	0.00	0.00	0.00	1.44	4.43	.50	1.63	.77	0.00	0.00	0.00	8.77
1974	0.00	0.00	0.00	1.00	3.00	.96	.48	1.88	0.00	0.00	0.00	0.00	7.32
1975	0.00	0.00	0.00	0.00	2.99	3.46	1.89	1.13	1.06	0.00	0.00	0.00	10.53
1976	0.00	0.00	0.00	1.12	1.95	4.00	1.64	.71	0.00	0.00	0.00	0.00	9.42
1977	0.00	0.00	0.00	.36	3.84	2.21	2.24	1.31	0.00	0.00	0.00	0.00	9.96
1978	0.00	0.00	0.00	.40	4.04	2.11	2.17	.66	0.00	0.00	0.00	0.00	9.38
1979	0.00	0.00	0.00	.32	2.33	3.66	.59	1.51	0.00	0.00	0.00	0.00	8.41
1980	0.00	0.00	0.00	.23	5.68	2.85	1.12	1.19	0.00	0.00	0.00	0.00	11.07
1981	0.00	0.00	0.00	.93	6.99	3.96	1.14	.39	0.00	0.00	0.00	0.00	13.41
1982	0.00	0.00	0.00	0.00	2.32	4.04	1.52	1.01	1.27	0.00	0.00	0.00	10.16
MEAN	0.00	0.00	0.00	.33	2.52	3.05	1.18	1.17	.21	0.00	0.00	0.00	8.48
S.D.	0.00	0.00	0.00	.42	1.35	1.51	.78	.78	.34	0.00	0.00	0.00	2.38
COEF. VAR.	+***.***	+***.***	+***.***	1.257	.538	.495	.665	.673	1.598	+***.***	+***.***	+***.***	.280
PERCENT OF ANNUAL MEAN	0.0%	0.0%	0.0%	4.0%	29.7%	36.0%	13.9%	13.8%	2.5%	0.0%	0.0%	0.0%	

SUM OF MONTHLY MEANS 8.5

Table IV.6

Effective Precipitation - Alfalfa

EFFECTIVE PRECIP. ALFALFA

FILE -- EFPRECA2
SITE -- BOZEMAN
UNIT -- IN
NOTE -- ANY MONTH WITH ****.** INDICATES NO DATA AVAILABLE 10/09/84

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL TOTAL
1931	0.00	0.00	0.00	0.00	1.73	1.50	1.46	.37	2.13	0.00	0.00	0.00	7.19
1932	0.00	0.00	0.00	0.00	.45	3.29	1.55	1.54	.21	.22	0.00	0.00	7.26
1933	0.00	0.00	0.00	0.00	.83	1.13	.40	3.48	1.87	.17	0.00	0.00	7.38
1934	0.00	0.00	0.00	0.00	.38	2.35	.40	0.00	1.06	.14	0.00	0.00	4.33
1935	0.00	0.00	0.00	0.00	.45	1.76	.77	.70	.15	.23	0.00	0.00	4.06
1936	0.00	0.00	0.00	0.00	1.31	2.13	0.00	1.48	1.04	0.00	0.00	0.00	5.96
1937	0.00	0.00	0.00	0.00	.56	3.90	2.16	.20	2.33	0.00	0.00	0.00	9.15
1938	0.00	0.00	0.00	0.00	1.63	1.82	1.20	.88	0.00	.30	0.00	0.00	5.83
1939	0.00	0.00	0.00	0.00	1.31	3.71	.69	.94	1.29	0.00	0.00	0.00	8.54
1940	0.00	0.00	0.00	0.00	1.11	2.39	.61	.45	2.48	0.00	0.00	0.00	7.64
1941	0.00	0.00	0.00	0.00	1.08	3.17	1.26	1.80	4.60	0.00	0.00	0.00	11.91
1942	0.00	0.00	0.00	0.00	0.00	2.68	.47	.53	1.54	.12	0.00	0.00	5.34
1943	0.00	0.00	0.00	0.00	0.00	2.50	1.30	1.24	.91	.19	0.00	0.00	6.74
1944	0.00	0.00	0.00	0.00	2.32	7.98	1.70	1.42	2.13	0.00	0.00	0.00	15.55
1945	0.00	0.00	0.00	0.00	.36	4.10	.76	1.73	1.84	0.00	0.00	0.00	8.79
1946	0.00	0.00	0.00	0.00	.59	1.38	1.47	.76	1.37	.23	0.00	0.00	6.40
1947	0.00	0.00	0.00	0.00	.88	6.78	.37	.80	4.58	0.00	0.00	0.00	13.41
1948	0.00	0.00	0.00	0.00	1.76	4.87	1.58	1.91	.60	0.00	0.00	0.00	10.72
1949	0.00	0.00	0.00	.27	1.92	3.73	.51	.55	.88	0.00	0.00	0.00	7.35
1950	0.00	0.00	0.00	0.00	.33	2.16	2.74	1.86	1.39	0.00	0.00	0.00	9.08
1951	0.00	0.00	0.00	0.00	.93	1.61	.87	2.36	2.01	0.00	0.00	0.00	7.78
1952	0.00	0.00	0.00	0.00	4.71	2.02	1.28	1.16	.56	0.00	0.00	0.00	9.73
1953	0.00	0.00	0.00	0.00	.52	3.13	.63	.42	1.00	.99	0.00	0.00	6.69
1954	0.00	0.00	0.00	0.00	1.15	3.70	.66	1.32	1.21	0.00	0.00	0.00	8.04
1955	0.00	0.00	0.00	0.00	1.31	2.23	1.55	.12	1.11	0.00	0.00	0.00	6.32
1956	0.00	0.00	0.00	0.00	1.33	1.06	.46	.95	.97	.43	0.00	0.00	5.20
1957	0.00	0.00	0.00	0.00	1.81	4.68	1.52	.70	.54	0.00	0.00	0.00	9.25
1958	0.00	0.00	0.00	0.00	.37	2.43	3.25	2.52	1.40	.28	0.00	0.00	10.25
1959	0.00	0.00	0.00	0.00	.92	2.42	1.63	.74	2.27	0.00	0.00	0.00	7.98
1960	0.00	0.00	0.00	0.00	1.05	1.19	.37	2.14	.32	0.00	0.00	0.00	5.06
1961	0.00	0.00	0.00	0.00	.85	.82	.71	.58	3.59	0.00	0.00	0.00	6.55
1962	0.00	0.00	0.00	0.00	1.74	1.55	3.08	2.14	0.00	0.00	0.00	0.00	8.51
1963	0.00	0.00	0.00	0.00	2.12	3.13	1.09	.80	2.00	.73	0.00	0.00	9.87
1964	0.00	0.00	0.00	0.00	1.81	3.72	.91	3.80	0.00	0.00	0.00	0.00	10.24
1965	0.00	0.00	0.00	0.00	.94	3.76	.68	2.23	1.29	0.00	0.00	0.00	8.90
1966	0.00	0.00	0.00	0.00	2.05	2.84	.46	1.26	1.08	.69	0.00	0.00	8.38
1967	0.00	0.00	0.00	0.00	.93	4.44	1.12	.27	1.21	.45	0.00	0.00	8.42
1968	0.00	0.00	0.00	0.00	.91	3.78	1.08	2.63	1.94	0.00	0.00	0.00	10.34
1969	0.00	0.00	0.00	0.00	1.92	7.37	1.70	1.50	.86	.49	0.00	0.00	13.84
1970	0.00	0.00	0.00	0.00	1.99	1.48	3.15	.97	.97	0.00	0.00	0.00	8.56
1971	0.00	0.00	0.00	0.00	1.49	2.86	.29	.70	1.45	0.00	0.00	0.00	6.79
1972	0.00	0.00	0.00	0.00	.95	3.07	1.20	1.44	1.60	0.00	0.00	0.00	8.26
1973	0.00	0.00	0.00	0.00	.84	4.43	.50	1.63	2.89	.17	0.00	0.00	10.46
1974	0.00	0.00	0.00	0.00	1.06	.96	.48	2.65	1.46	.31	0.00	0.00	6.92
1975	0.00	0.00	0.00	0.00	.63	3.46	1.89	1.13	1.67	3.18	0.00	0.00	11.96
1976	0.00	0.00	0.00	0.00	1.76	4.00	1.64	.79	3.29	.86	0.00	0.00	12.34
1977	0.00	0.00	0.00	0.00	2.35	2.21	2.24	2.13	2.88	.46	0.00	0.00	12.27
1978	0.00	0.00	0.00	0.00	1.82	2.11	2.17	.82	4.22	.34	0.00	0.00	11.48
1979	0.00	0.00	0.00	0.00	1.43	3.66	.59	1.51	0.00	.45	0.00	0.00	7.64
1980	0.00	0.00	0.00	0.00	5.68	2.85	1.12	1.85	3.40	.38	0.00	0.00	15.28
1981	0.00	0.00	0.00	0.00	4.28	3.96	1.14	.50	1.31	.34	0.00	0.00	11.53
1982	0.00	0.00	0.00	0.00	.93	4.04	1.52	1.01	2.32	.35	0.00	0.00	10.77
MEAN	0.00	0.00	0.00	.00	1.39	3.05	1.21	1.29	1.63	.24	0.00	0.00	8.84
S.D.	0.00	0.00	0.00	.03	1.06	1.51	.76	.83	1.14	.48	0.00	0.00	2.62
COEF. VAR.	+***.***	+***.***	+***.***	7.211	.761	.495	.635	.641	.698	2.011	+***.***	+***.***	.297
PERCENT OF ANNUAL MEAN	0.0%	0.0%	0.0%	.1%	15.3%	34.6%	13.7%	14.7%	18.5%	2.7%	0.0%	0.0%	

SUM OF MONTHLY MEANS 8.8

Table IV.7

Weighted Net Irrigation Requirement

WEIGHTED IRRIGATION REQUIREMENT

FILE -- IWIR2WYR
SITE -- MIDDLE CREEK AVAILABILITY
UNIT -- INCHES
NOTE -- ANY MONTH WITH ****** INDICATES NO DATA AVAILABLE

10/10/94

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL TOTAL
1931	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.7	4.0	5.5	3.9	.6	14.9
1932	.1	0.0	0.0	0.0	0.0	0.0	0.0	1.6	1.5	5.0	2.5	1.7	12.7
1933	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.2	4.3	7.3	1.0	.6	13.6
1934	.0	0.0	0.0	0.0	0.0	0.0	1.0	3.5	2.7	5.4	3.7	.9	17.5
1935	.0	0.0	0.0	0.0	0.0	0.0	0.0	.1	2.4	6.2	4.2	2.1	15.2
1936	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.4	3.4	8.0	2.7	1.2	17.3
1937	.1	0.0	0.0	0.0	0.0	0.0	0.0	1.5	.5	4.8	4.2	.6	11.9
1938	.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.9	5.2	3.6	2.5	14.4
1939	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	.5	5.5	2.8	1.1	11.4
1940	.1	0.0	0.0	0.0	0.0	0.0	0.0	1.6	2.4	6.3	3.9	.5	14.9
1941	.1	0.0	0.0	0.0	0.0	0.0	0.0	1.2	1.7	5.2	2.2	0.0	10.7
1942	.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	6.1	3.8	.8	12.1
1943	.0	0.0	0.0	0.0	0.0	0.0	0.0	.0	1.8	3.9	2.4	1.3	9.6
1944	.0	0.0	0.0	0.0	0.0	0.0	.0	.2	0.0	3.9	2.1	.5	6.8
1945	.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.8	3.2	.5	9.7
1946	.1	0.0	0.0	0.0	0.0	0.0	0.0	.0	3.5	4.5	2.8	.5	11.7
1947	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8	0.0	6.9	3.3	0.0	12.1
1948	.1	0.0	0.0	0.0	0.0	0.0	0.0	.6	.5	4.5	2.0	1.7	9.6
1949	.2	0.0	0.0	0.0	0.0	0.0	.0	1.5	1.0	5.6	3.5	.3	12.4
1950	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.1	2.0	3.2	2.4	.6	8.5
1951	.1	0.0	0.0	0.0	0.0	0.0	0.0	.8	2.0	5.8	1.5	.2	10.5
1952	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.4	4.6	2.8	1.7	12.6
1953	.2	0.0	0.0	0.0	0.0	0.0	0.0	.0	1.2	6.9	5.1	1.5	15.1
1954	.2	0.0	0.0	0.0	0.0	0.0	.0	.9	.7	6.6	2.5	1.1	12.3
1955	.0	0.0	0.0	0.0	0.0	0.0	0.0	.2	2.0	2.9	3.8	1.1	10.3
1956	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.6	4.5	6.5	2.9	1.5	16.2
1957	.2	0.0	0.0	0.0	0.0	0.0	.0	.3	.1	5.3	3.8	1.0	10.9
1958	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.7	2.5	2.5	2.1	.9	11.9
1959	.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.7	5.4	3.8	.2	12.8
1960	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.3	3.8	7.3	1.9	1.3	14.8
1961	0.0	0.0	0.0	0.0	0.0	0.0	.0	1.0	5.4	6.9	4.6	0.0	18.1
1962	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.8	2.6	1.8	.2	8.6
1963	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.1	1.6	5.7	3.8	1.1	12.5
1964	.6	0.0	0.0	0.0	0.0	0.0	0.0	.1	.8	6.6	.7	.7	9.7
1965	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.9	5.8	1.7	0.0	8.5
1966	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.6	1.7	7.0	2.8	1.5	13.8
1967	.0	0.0	0.0	0.0	0.0	0.0	0.0	.3	.0	6.1	4.9	1.6	13.2
1968	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.6	5.7	1.2	.0	7.7
1969	0.0	0.0	0.0	0.0	0.0	0.0	.0	1.5	0.0	4.3	2.8	1.6	10.4
1970	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.1	3.9	4.1	4.4	.2	12.9
1971	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.5	1.8	5.2	4.6	.2	13.5
1972	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.6	2.4	4.9	3.3	.4	11.8
1973	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.3	.5	5.7	3.2	0.0	11.3
1974	.0	0.0	0.0	0.0	0.0	0.0	0.0	.1	5.5	6.6	1.5	.9	14.3
1975	.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.6	5.8	3.5	.8	10.3
1976	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	.9	5.3	3.1	.0	10.3
1977	.0	0.0	0.0	0.0	0.0	0.0	.0	0.0	4.0	3.6	1.9	.0	9.3
1978	.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.2	4.0	3.0	0.0	10.4
1979	.3	0.0	0.0	0.0	0.0	0.0	0.0	.5	1.7	6.5	2.9	2.5	14.5
1980	.1	0.0	0.0	0.0	0.0	0.0	.1	0.0	2.5	5.1	1.9	0.0	9.9
1981	.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.9	5.3	3.9	1.3	11.9
1982	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.1	.5	5.5	4.3	0.0	10.5
MEAN	.0	0.0	0.0	0.0	0.0	0.0	.0	.6	2.0	5.4	3.0	.8	12.1
S.D.	.1	0.0	0.0	0.0	0.0	0.0	.1	.8	1.4	1.2	1.0	.6	2.5
COEF. VAR.	1.532	+***.***	+***.***	+***.***	+***.***	+***.***	5.127	1.287	.744	.224	.342	.920	.208
PERCENT OF ANNUAL MEAN	.3%	0.0%	0.0%	0.0%	0.0%	0.0%	.2%	5.5%	16.5%	45.1%	25.1%	6.9%	

SUM OF MONTHLY MEANS 12.2

SURFACE WATER SUPPLY

The Hydrologic Potential For The Hyalite Creek Watershed has been reported in a detailed report dated November 1983, HKM Associates. This study addresses watershed yield without storage effects. The following paragraphs summarize this study.

A suitable study period used in establishing the hydrologic potential for the Hyalite Creek watershed was determined to be 1931 through 1982. Given long term climatic precipitation data, the selected study period appears to be slightly above a long term average or "surplus." The period does include the widely recognized sustained dry period during the 1930's. Also included in the study period is a sustained surplus period through the 1960's and 1970's, and average conditions particularly during the 1940 to 1960 timespan. The study period does exhibit strong persistence similar to longer record periods. The above comments relating to climate conditions are assumed applicable to corresponding hydrologic conditions because precipitation is the primary input to runoff. The period 1931-82 is acceptably representative of long-term hydrologic conditions.

The hydrologic potential analysis focused on two primary locations of interest within the Hyalite Creek Watershed: Hyalite Creek at Hyalite Ranger Station, which is near the mouth of Hyalite Canyon, and Hyalite Creek at Middle Creek Dam. Monthly sequential streamflows were generated for the period 1931-82. The long-term mean monthly, unregulated flow for Hyalite Creek near the canyon mouth is estimated to be 46,708 AF. The 50% chance and 80% chance flows at this location are 45,610 AF and 37,532 AF, respectively. Relative to Hyalite Creek at the dam (also referred to as reservoir inflows), the long-term mean annual flow is estimated to be 34,768 AF. The 50% chance flow is 34,009 AF and the 80% chance flow is 27,346 AF. See Tables IV.8 and IV. 9 for a tabulation of monthly streamflows.

Table IV.8

Monthly Streamflow (Estimated)
At Middle Creek Dam

MONTHLY STREAMFLOW (ESTIMATED)

FILE -- MCFINAL
SITE -- MIDDLE CREEK DAM INFLOW
UNIT -- AC-FT
NOTE -- ANY MONTH WITH ******* INDICATES NO DATA AVAILABLE 10/09/84

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL TOTAL
1931	1801	1126	979	602	935	1096	1689	5388	5328	1546	967	700	23264
1932	746	972	948	873	825	949	1134	7069	13864	4247	1733	1355	34617
1933	1238	1035	855	923	750	925	1244	3259	11022	2998	1634	1363	27133
1934	1039	965	944	967	817	963	1953	3722	2207	1152	866	528	16109
1935	694	565	321	233	264	367	638	5079	11000	5596	1787	938	27489
1936	808	638	606	425	306	481	2903	5629	4019	1269	986	767	13845
1937	800	663	581	469	311	455	752	6592	7376	2402	1018	905	22329
1938	940	590	445	475	349	541	1447	6357	8629	2968	1577	978	25201
1939	1189	923	840	694	422	614	1827	6697	5033	3558	1431	1083	25323
1940	938	646	574	654	355	629	1262	8192	9471	3114	1423	1107	28171
1941	1051	696	614	776	606	736	1286	5241	5710	1997	1220	2522	22458
1942	2385	1423	1286	969	565	743	3025	5685	9509	6251	1965	1333	34146
1943	1229	1035	776	719	687	606	3025	6033	11226	6430	2029	1253	35054
1944	1229	1156	767	654	638	606	800	6268	11049	5920	1972	1903	32973
1945	1608	962	696	638	638	574	783	6486	9447	7231	1997	1512	32577
1946	1431	1196	1051	889	889	945	3534	5346	7190	4286	2134	1601	30696
1947	1415	1286	856	590	490	552	1593	9973	11299	7724	2790	2426	40999
1948	1997	1318	1253	1213	606	945	5645	14195	12553	4917	3461	2200	50307
1949	1779	1552	1237	727	760	492	2272	6796	7699	3130	1471	1506	29423
1950	1391	969	873	654	687	687	1213	4674	9592	5960	2482	1633	30821
1951	1415	1213	1156	962	551	277	2296	8201	5289	4003	1859	1431	28657
1952	1406	949	736	1019	606	654	2952	9827	11136	4480	2151	1350	37221
1953	1067	760	767	691	926	637	1350	4319	10668	5872	1666	1366	30093
1954	1244	945	996	675	795	1023	1415	6122	8338	5346	2127	1067	29900
1955	832	677	1068	798	574	589	744	6373	10603	4723	1876	913	29776
1956	1140	660	859	679	455	686	1981	5467	9390	2409	1326	1253	26310
1957	1148	375	825	540	485	682	881	5670	12423	4327	1520	1326	30706
1958	1131	940	816	792	625	655	1375	9374	7061	3380	1868	1196	29119
1959	1002	938	816	776	505	679	1657	7263	15788	7020	2127	1319	40394
1960	1883	1455	1018	825	808	945	2571	5791	10927	4554	2102	1173	34057
1961	986	881	552	321	569	682	1213	5379	7392	1633	1164	1269	22045
1962	1997	1067	783	657	637	776	3664	7344	9585	5581	2733	1763	36591
1963	1528	601	1253	703	805	954	1965	9261	11016	4512	2143	1471	36216
1964	1204	881	545	323	385	500	1989	9123	12464	7877	2790	1795	39892
1965	1593	969	1479	1035	808	1027	1674	8667	15464	10385	3178	2571	43656
1966	1933	1454	1100	905	796	864	1722	8993	8323	4117	2272	1318	33798
1967	1406	856	1013	741	591	780	969	8201	14399	7877	2207	1495	40532
1968	1803	1471	1237	1083	849	1051	1309	8961	14858	10288	4787	3429	51132
1969	2968	1479	1042	1180	736	1035	3558	14235	11688	8112	2498	1916	50453
1970	1714	1075	1115	889	945	954	865	14090	20164	9252	3347	2628	57045
1971	2240	1584	1011	885	1027	1011	1471	10248	14785	9406	3485	2451	49608
1972	2118	1350	861	857	834	1431	1795	7036	10135	4505	1431	1601	33960
1973	1617	1107	783	535	530	1087	775	10669	12172	5661	1908	1997	39845
1974	1520	1489	921	1156	698	703	2167	8079	18667	8032	2555	1941	47931
1975	1907	1944	1566	1442	1084	1108	1079	3896	17916	18717	3694	1972	56207
1976	2038	1506	1190	923	697	671	1311	8348	12693	9164	2919	1773	43229
1977	1707	996	802	703	520	607	1961	5561	10320	3115	1552	1521	29148
1978	1815	1167	884	820	778	839	1404	5196	11707	10867	2536	1831	39850
1979	1274	1145	982	1049	772	1013	1168	7009	12754	5890	1930	1683	36673
1980	2065	1824	1920	1461	901	793	2859	9056	9480	3504	1792	1915	37574
1981	1373	1217	1124	923	944	698	1556	7569	11719	5293	1722	1196	34980
1982	1324	1014	853	1285	1074	1066	1151	5233	11877	9565	2903	2245	39595
MEAN	1462	1075	934	800	670	765	1736	7289	10682	5620	2098	1582	34768
S.D.	472	320	294	265	199	234	952	2469	3528	3128	779	558	9349
COEF. VAR.	.323	.297	.304	.331	.298	.306	.533	.338	.330	.556	.371	.352	.268
PERCENT OF ANNUAL MEAN	4.2%	3.1%	2.7%	2.3%	1.9%	2.2%	5.1%	21.0%	30.7%	16.2%	6.0%	4.6%	

SUM OF MONTHLY MEANS 34,768.1

Table IV.9

Monthly Streamflows
At Hyalite Ranger Station

MONTHLY STREAMFLOWS

FILE -- HYURE6E4
SITE -- HYALITE CR. (MIDDLE CR. NEAR BOZEMAN) AT HYALITE RANGER STA.
UNIT -- AC-FT
NOTE -- ANY MONTH WITH ******* INDICATES NO DATA AVAILABLE 10/09/84

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL TOTAL
1931	2537	1704	1521	1055	1468	1666	2399	6973	3134	2346	1506	1177	32486
1932	1231	1513	1483	1391	1330	1361	1712	9051	17451	5561	2453	1987	46524
1933	1842	1590	1368	1452	1239	1330	1849	4339	13938	4018	2331	1972	37268
1934	1595	1479	1478	1506	1322	1502	2725	4913	3040	1735	1381	964	23640
1935	1170	1010	708	599	637	764	1100	6590	13910	7230	2520	1470	37708
1936	1310	1100	1060	837	690	906	3900	7270	5280	1880	1530	1260	27023
1937	1300	1130	1030	891	696	873	1240	8460	3430	3280	1570	1430	31330
1938	1350	1040	861	899	742	980	2100	8170	10980	3980	2260	1520	34882
1939	1790	1460	1350	1170	833	1070	2570	8590	7770	4710	2080	1650	35033
1940	1470	1110	1020	1120	750	841	1870	10640	12020	4160	2070	1580	39551
1941	1610	1170	1070	1270	1060	1220	1900	6790	7370	2780	1820	3430	31490
1942	3260	2070	1900	1510	1010	1230	4050	7340	10830	8040	2740	1960	45940
1943	1830	1590	1270	1200	1160	1060	4050	7770	14190	8260	2820	1960	47050
1944	1930	1740	1260	1120	1100	1060	1300	8060	13970	7630	2750	2670	44490
1945	2300	1500	1170	1100	1100	1020	1280	8330	11990	9250	2780	2180	44000
1946	2080	1790	1610	1410	1410	1480	4680	6920	9200	5610	2950	2290	41430
1947	2060	1900	1370	1040	916	994	2230	12640	14280	9960	3760	3310	54410
1948	2780	1940	1860	1810	1060	1480	7290	17860	15830	6390	4590	3030	65920
1949	2510	2230	1840	1210	1250	920	3120	8710	9830	4180	2130	2170	40100
1950	2030	1510	1390	1120	1160	1160	1910	6090	12170	7680	3380	2330	41830
1951	2060	1910	1740	1500	992	653	3150	10650	6850	5260	2610	2080	39155
1952	2050	1360	1220	1570	1060	1120	3960	12460	14140	5850	2970	1980	49740
1953	1630	1251	1250	1165	1455	1099	1990	5650	13500	7570	2370	2000	40930
1954	1850	1480	1543	899	1295	1575	2060	7980	10620	6920	2940	1630	40692
1955	1340	1149	1631	1298	1021	1039	1231	8190	13420	6150	2630	1440	40539
1956	1720	1128	1373	1150	873	1159	2760	7070	11920	3290	1950	1960	36253
1957	1730	1392	1330	979	910	1155	1400	7320	15670	5660	2190	1950	41686
1958	1710	1350	1320	1290	1083	1121	2010	11900	9040	4490	2620	1790	39724
1959	1550	1470	1320	1270	935	1150	2360	9290	19830	8990	2940	2560	53665
1960	2640	2110	1570	1330	1310	1480	3490	7470	13820	5940	2910	1760	45830
1961	1530	1400	993	707	1014	1155	1810	6960	9450	2330	1750	1880	30979
1962	2790	1630	1290	1123	1099	1270	4840	9390	12160	7210	3690	2490	48962
1963	2200	1053	1860	1180	1307	1490	2740	11760	13930	5990	2960	2130	48500
1964	1800	1400	985	710	798	929	2770	11590	15720	10050	3760	2530	53032
1965	2280	1510	2140	1590	1310	1580	2380	10780	19430	13150	4240	3490	63890
1966	2701	2108	1671	1430	1293	1379	2440	11430	10600	5400	3120	1940	45512
1967	2050	1370	1563	1226	1041	1275	1510	10450	18100	10050	3040	2160	53835
1968	2540	2130	1840	1650	1360	1610	1930	11390	19680	13030	5230	4550	66940
1969	3990	2140	1600	1770	1221	1590	4710	17910	14760	10340	3400	2680	66101
1970	2430	1540	1690	1418	1480	1490	1330	17730	25240	11750	4450	3560	74250
1971	3080	2270	1560	1405	1580	1560	2130	12980	18590	11940	4620	3340	65055
1972	2930	1980	1376	1371	1342	2080	2530	9010	12840	5980	2080	2290	45709
1973	2310	1680	1280	972	967	1655	1268	13500	15360	7310	2670	2780	51752
1974	3190	2150	1650	1740	1174	1180	2990	10300	23330	10240	3470	2710	62994
1975	2200	1650	1250	1630	1470	1700	1320	5620	22010	17480	3840	3150	63320
1976	2980	2630	2130	1790	1650	1670	3260	15350	13970	9620	3650	2910	61610
1977	2790	1780	1500	1323	1272	1716	4110	8900	10420	3650	2240	2030	41729
1978	2970	1730	1630	1430	1310	1760	3820	11910	12230	9620	3360	3420	55190
1979	2560	2040	1500	1440	1190	1540	2230	9770	14110	6290	3150	2280	49150
1980	1620	1520	1310	1250	1150	1410	3880	11840	10080	4520	2230	1980	42790
1981	2110	1700	1490	1410	1074	1300	3100	15730	16070	6300	2430	2430	55144
1982	2270	1660	1910	1010	1240	1240	2280	9040	16050	10350	3770	3270	54090
MEAN	2124	1620	1441	1264	1138	1289	2636	9737	13338	6944	2878	2295	46708
S.D.	594	371	305	283	237	297	1205	3220	4376	3258	926	720	11374
COEF. VAR.	.279	.229	.212	.223	.208	.230	.457	.330	.328	.469	.321	.313	.243
PERCENT OF ANNUAL MEAN	4.5%	3.5%	3.1%	2.7%	2.4%	2.8%	5.6%	20.8%	28.6%	14.9%	6.2%	4.9%	

SUM OF MONTHLY MEANS 46,708.5

WATER RIGHTS

Storage rights held by the State of Montana in Hyalite Reservoir are junior to over 97% of the claimed direct flow rights in the basin. Except for May and June, inflows to the reservoir normally are released to meet the demands of the senior direct flow rights. Storage occasionally occurs in other months during brief storm runoff periods.

In most years direct flows diminish to levels below the agricultural demands about mid-July. Holders of contracts for stored water then request releases from Hyalite Reservoir. The Middle Creek Water Users Association has the responsibility of regulating these flows from storage. In critically dry years, it often becomes necessary for the district court to appoint a water commissioner to regulate diversions from Middle Creek to direct flow and storage contract holders.

Direct Flows

The Montana State Engineer in 1953 reported numerous water rights on Hyalite Creek and its tributaries. (Refer to the Montana State Water Resources Survey for Gallatin County, Montana). Two decrees (42 rights) and 67 filed appropriations of water were reported. These total over 740 cfs which exceeds the peak flow of record. It is obvious that this overstates actual usage since surplus flows are known to exist.

According to state law, failure to claim all non-decreed water rights means abandonment of a right. The procedure adopted herein to quantify agricultural demands utilizes recent SB76 water rights claims.

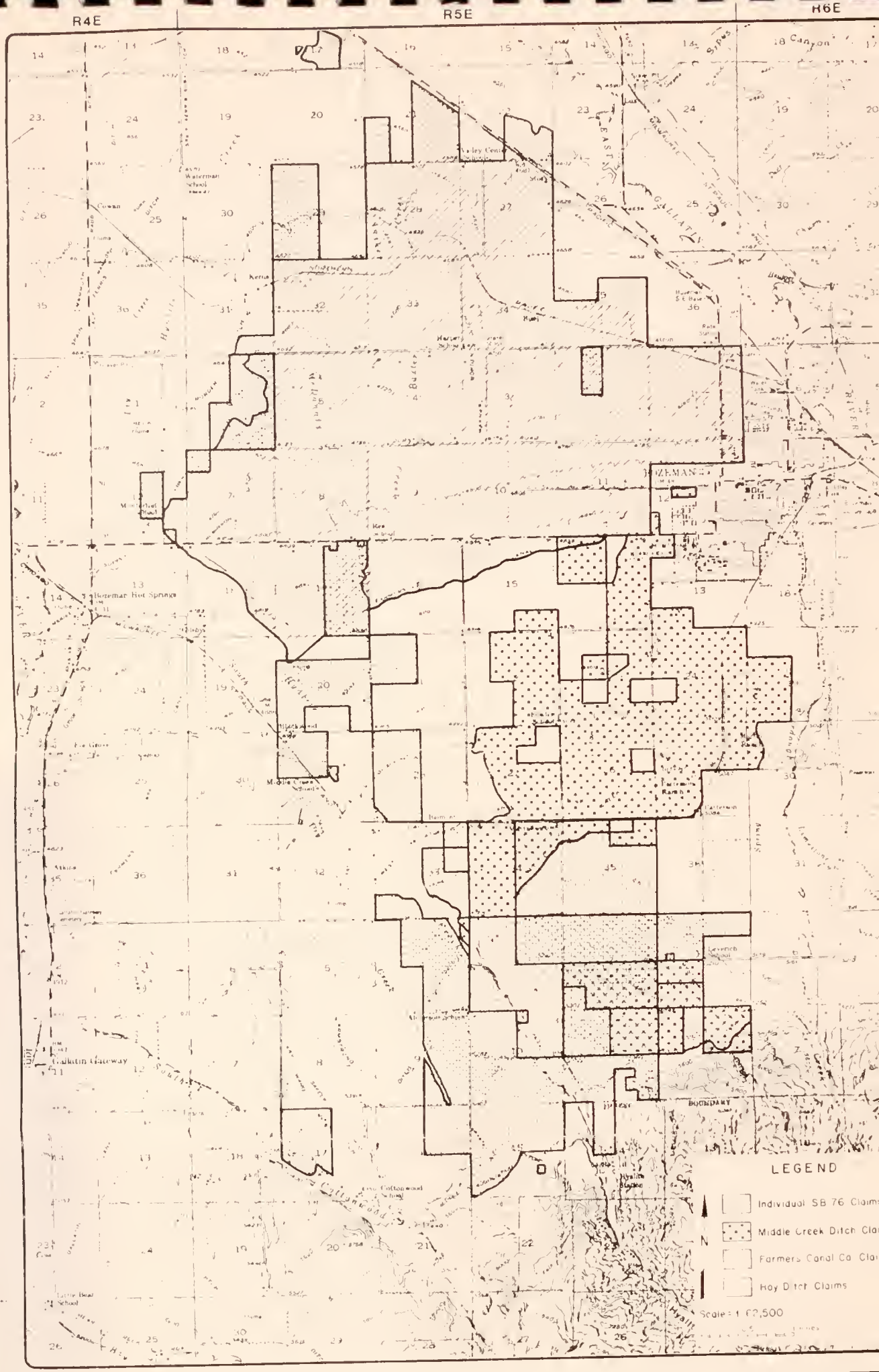
Senate Bill (SB)76 claims. SB76 claims of record were obtained from the Montana Water Rights Bureau. Irrigation claims were plotted on a legal land description base map according to the claimed service area description. Several overlaps were noted. (See Figure IV.1.) An additional procedure as described in the following section was used to eliminate these duplications.

Direct Flow Irrigation. Several sources were used to determine the best description of direct flow irrigation area. The SB76 claims, Montana Water Resources Survey and aerial photography were used to determine under which ditch or subarea each acre was served. See Figure IV.2 for the results of this determination. A total of 24,819 acres were identified as being served by direct flow rights from Hyalite Creek. A breakdown of this acreage by ditch or subarea is shown on Table III.1.

DNRC Storage Claims

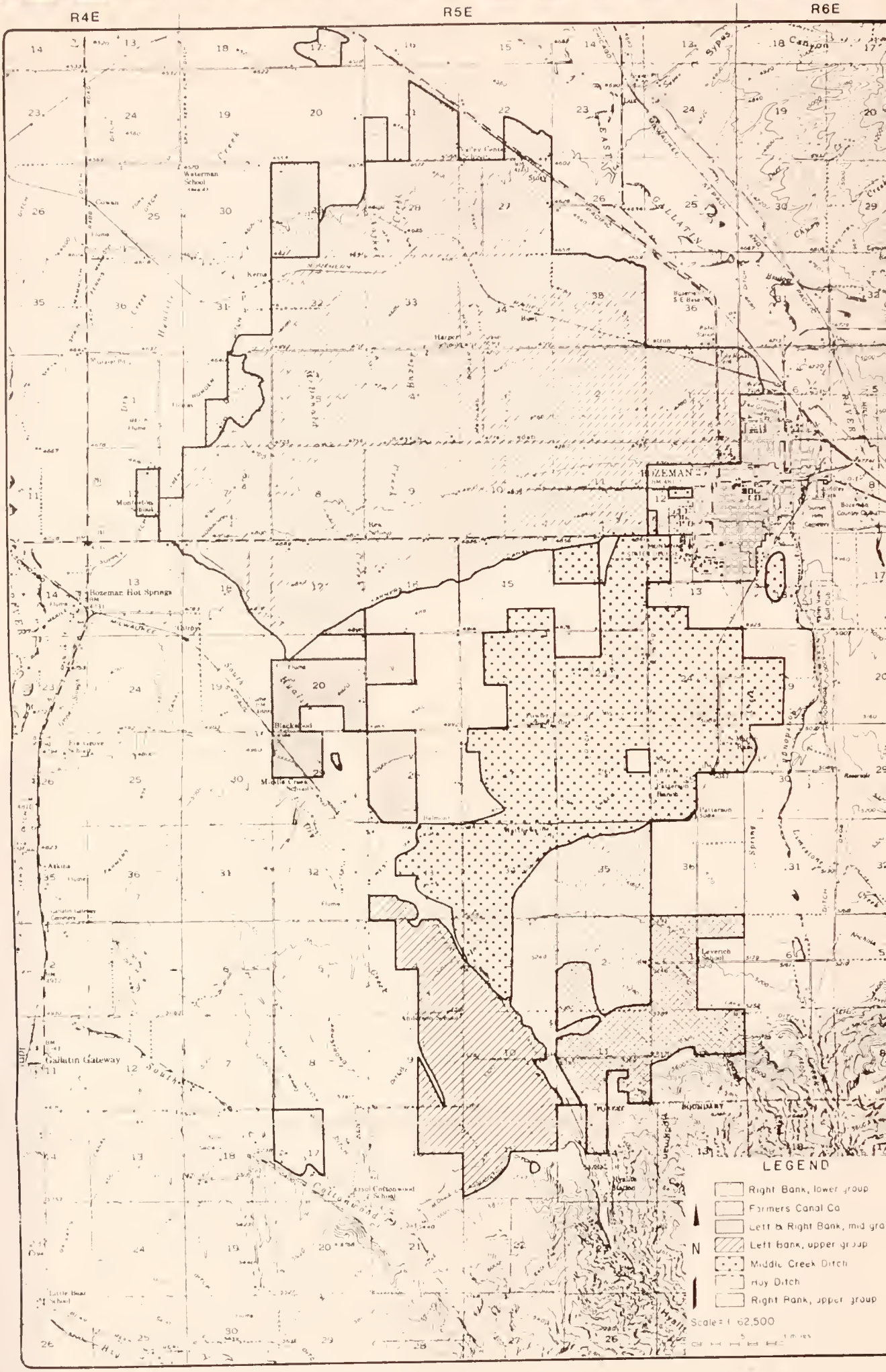
Water right claims made by the state for the Middle Creek Dam project were made as a part of the SB76 claims process. The Engineering Bureau of DNRC claim a priority date of July 12, 1938 for the following appropriations:

.	Irrigation	92,000 cfs maximum diversion rate
		73,047 AF maximum annual volume
		30,420 acres of irrigation
.	Stockwater	30 cfs maximum rate
		376 AF maximum annual volume
		11,400 animal-units



MIDDLE CREEK DAM REHABILITATION

FIGURE IV



MIDDLE CREEK DAM REHABILITATION

FIGURE IV

.	Industrial Storage (Municipal)	92,000 cfs maximum diversion rate 8,027 AF maximum annual volume
.	Industrial Use (Municipal)	15 cfs maximum diversion rate 2,000 AF maximum annual volume

Storage Contracts

Three-party contracts for delivery of storage water at the dam of 7,810 AF have been entered into by the state, the Middle Creek Water Users Association, and the individual users. These contracts do not specify the land to which storage water is to be applied. The state has defined an area in which its SB76 claims are to be applied. Additional specificity is required for the purposes of this investigation and loan application to the USBR.

The storage service area shown in Figure III.1 was delineated by using the current contract purchasers (as of 5-24-83) noted in Appendix C, ownerships recorded at the courthouse and the Gallatin County ASCS office, and a telephone survey. Ninety-seven percent of the ownerships were determined through this process. The potential service area based on ownership is plotted on Figure III.1 and divided by canal or subarea in Table III.1. A total of 14,912 acres of ownership were identified. It is assumed that 240 acres (or 60%) of each typical 400-acre farm unit are irrigated. Therefore, it is assumed that 8,947 acres of land can be served by Middle Creek storage at the present time.

WATER UTILIZATION

A 10-foot increase in dam height is proposed to accommodate the auxiliary spillway construction and provide additional storage for M & I use. Correspondingly, 10.2 feet is proposed to be added to the existing normal pool level. This increase in spillway elevation will increase the active storage pool by 2,334 AF. It should be noted that flashboards have historically been in place over the crest of the existing spillway. These flashboards are 2 feet in height and have increased storage by 417 AF. This increment of storage has not been marketed. Since the flashboards should not be in place to accommodate a flood, the flashboards were not considered in the water utilization or hydraulic analysis. However, the additional storage is considered in the water rights, historical operation and environmental analysis. If the flashboards are considered, the actual increase in the water surface elevation is 8.2 feet instead of 10.2 feet.

In order to evaluate the potential for developing additional storage in Hyalite Reservoir, it was necessary to gain an understanding of water utilization in the basin. Conclusions are based primarily on historic records (available for 1952 only), discussions with people familiar with the system, and published data for the area. Since new storage would take place during the high runoff period, only the months of May and June were studied.

Models

Two models were used to evaluate water utilization for Middle Creek Dam. The first model was developed by HKM Associates to estimate storable flow for the study period of 1931-1982. The second model was the U.S. Army Corps of Engineers HEC-3

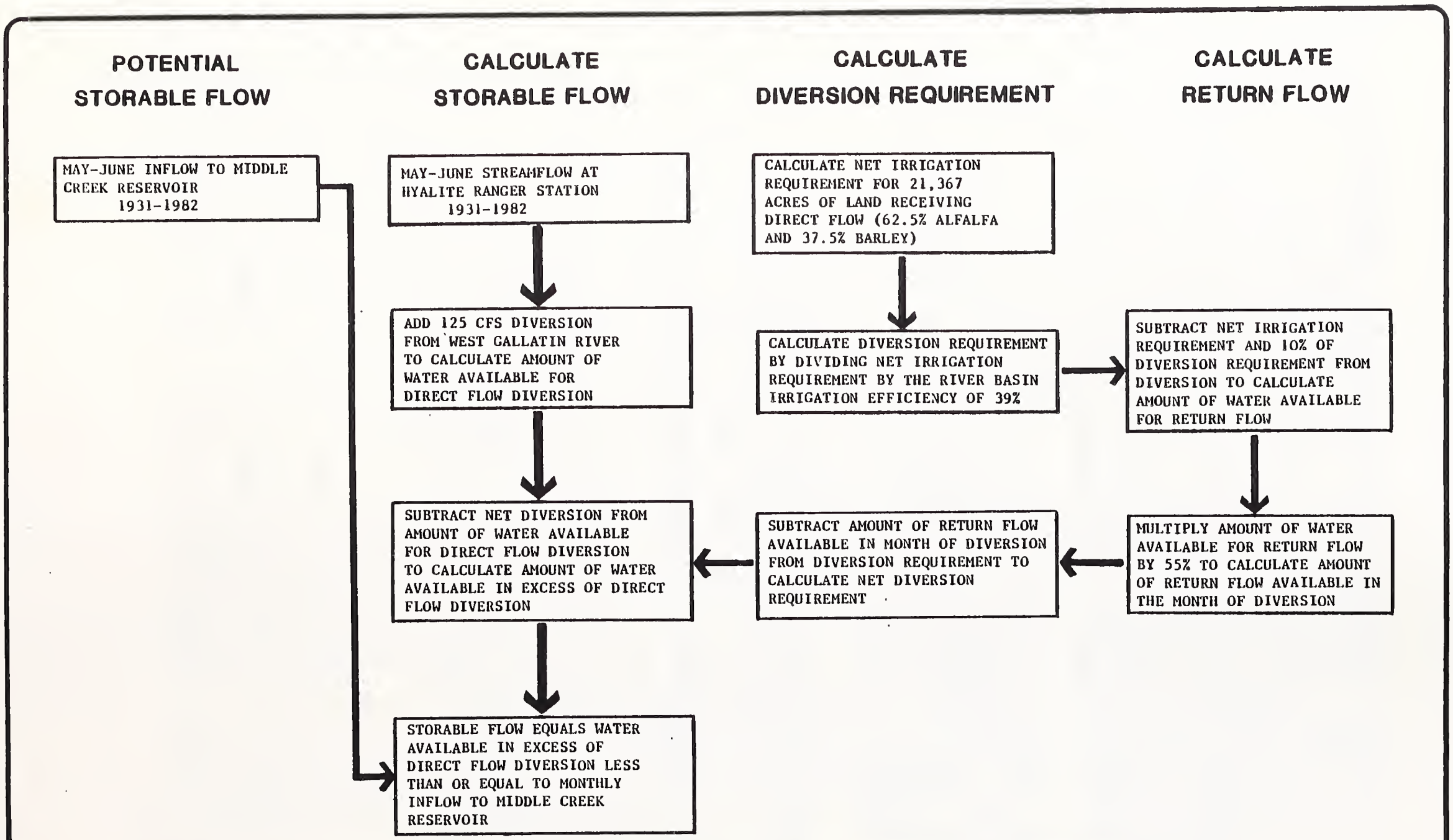
computer program, Reservoir System Analysis for Conservation, which was used to evaluate the difference in reservoir operation between historic and proposed conditions.

Storable Flow Model. The storable flow model was developed by HKM Associates and is presented in Figure IV.3. The logic of the model is based primarily on data available for 1952. The year 1952 was selected because USGS streamflow measurements for Hyalite Creek at Belgrade are available for this year only.

The study period for this model is 1931-1982 as described in the report Hydrologic Potential For The Hyalite Creek Watershed, HKM Associates, November 1983. Since new storage would take place in the high runoff period, only the months of May and June were studied.

The storable flow model was calibrated for the year 1952 in which the most data is available. Since the net irrigation requirement for May 1952 was zero, only June 1952 was evaluated. Information available for the Hyalite Creek Basin is presented below:

1. USGS streamflows for Hyalite Creek at Hyalite Creek Ranger Station.
2. USGS streamflows for Hyalite Creek at Belgrade.
3. Approximately 60 percent of lands in the service area (Figure III.1) and all lands receiving direct flow outside of the service area (Figure IV.2) are being irrigated. These lands cover 21,367 acres.
4. The cropping pattern for these 21,367 acres consists of 62.5% alfalfa, and 37.5% barley.
5. Approximately 125 cfs is available through the Farmers Canal from the West Gallatin River. This is based on a review of water rights and discussions with water users in the basin.



MIDDLE CREEK DAM REHABILITATION

STORABLE FLOW DIAGRAM

8M087.113

SEPTEMBER 1984

FIGURE IV. 3

HKM ASSOCIATES
ENGINEERS — PLANNERS

6. Demand for the City of Bozeman in 1952 was approximately 4 cfs in June of 1952. This is based on information from the City of Bozeman that indicates current demand can approach 9 cfs in a dry year and demand in 1952 was approximately half of current demand.

The following conclusions were drawn based on the June 1952 calibration:

1. River basin irrigation efficiency is approximately 39%. This efficiency reflects primarily flood irrigation which was prevalent in the 1950's.
2. Return flow equal to approximately 55% of the amount of water available for return flow in the month.
3. Nonbeneficial consumptive use in the basin is approximately 10% of the water diverted but not consumptively used by the crops.
4. The net irrigation requirement for June 1952 was 3.4 inches as compared to the 1931-1982 average and maximum values of 2.0 and 5.5 inches, respectively. Since the system experienced above average demand in June 1952, these conclusions are conservatively representative of other years during the period 1931-1982.
5. These conclusions relative to June are appropriate for May also.

The calibrated storable flow model was then used to generate May and June storable flows for the period 1931-1982. In order to determine how much of the storable flow would be available for storage in the enlarged portion of the pool, it was necessary to estimate the probable pool volume on April 30 preceding the months of May and June when storage would take place. April 30 storage records for the period 1952-1982 were reduced by 1,140 AF to reflect the amount of winter diversion

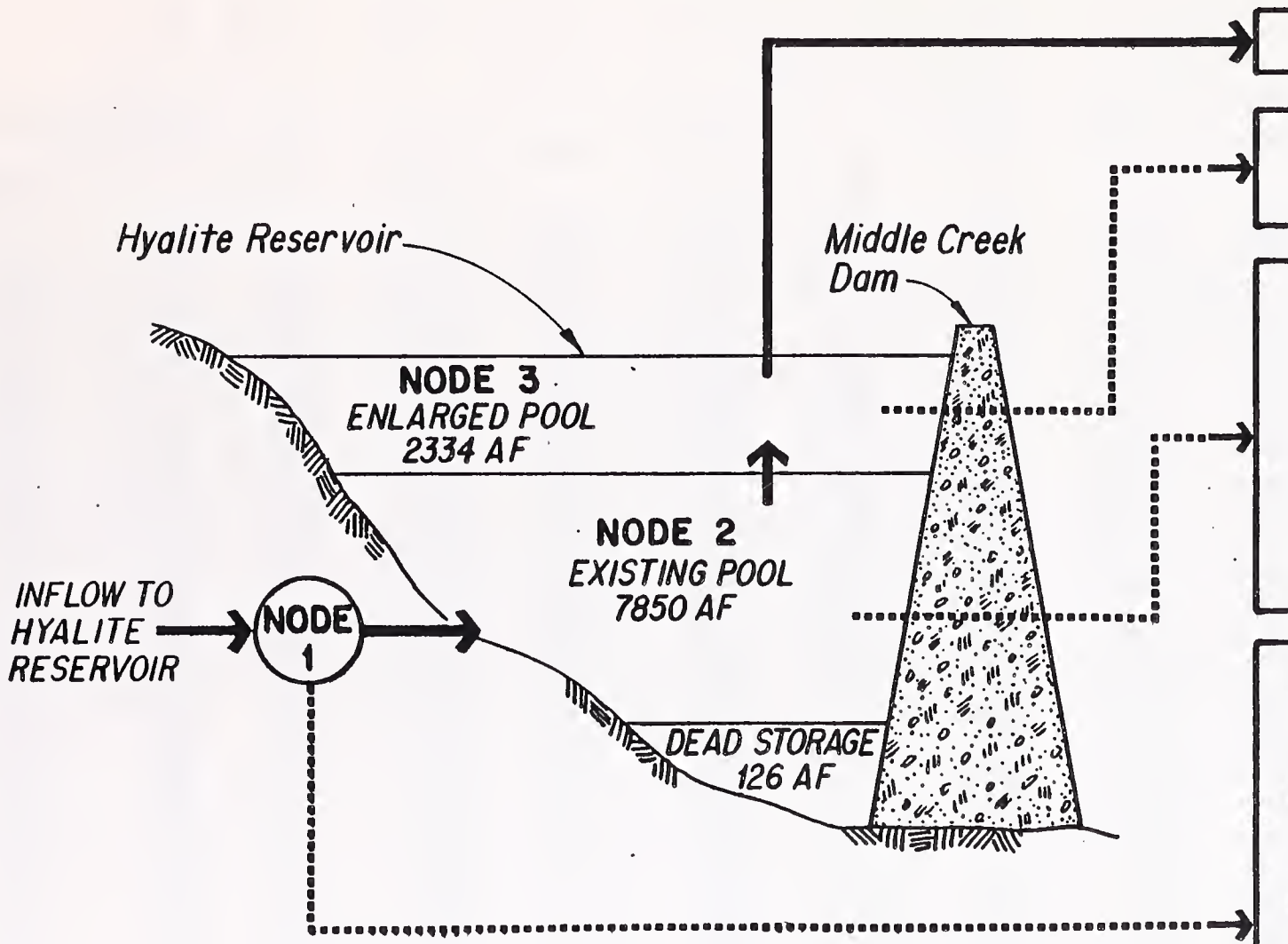
granted the City of Bozeman by DNRC in 1984. A statistical analysis of the April 30 storage records indicates a pool volume of at least 2,280 AF can be anticipated in 90 of 100 years. The computed storable flow for May and June was added to the assumed April 30 storage of 2,280 AF. The results indicate that the entire enlarged reservoir pool of 2,334 AF could be filled during May and June in 91 of 100 years. In the remaining 9 of 100 years no storable flow is available to the enlarged portion of the reservoir. However, in 8 of the 9 years without storable flow carryover, storage of 389 AF is possible. These 8 years were preceded by years in which there was storable flow in excess of space available in the reservoir. Therefore, the 389 AF[1/] that would have been released to the City of Bozeman in May and June could be served with direct flow and 389 AF could be carried over in storage to the following year.

HEC-3 Model. The U.S. Army Corps of Engineers Model, Reservoir System Analysis for Conservation, was used to evaluate the difference in reservoir operation between historic and proposed operation. A diagram of the HEC-3 model is presented in Figure IV.4. The HEC-3 model was operated for the period 1952-1982 when historic reservoir pool volume were available (see Table IV.10).

The following changes were made to the historic release schedule of the reservoir to reflect proposed conditions:

1. An additional 2,334 AF of storage was added (10 feet increase in normal pool level).
2. A demand of 195 AF/month (2,334 AF/12 months) was added to reflect future demand of the City of Bozeman on this storage.

1/ The additional 2,334 AF that would be stored in the enlarged portion of Middle Creek Reservoir would be released in 12 equal parts (i.e. 2,334 / 12 = 195 AF). The amount released in May and June would be (2 / 12) x 2,334 AF = 389 AF.



MIDDLE CREEK DAM REHABILITATION

HEC-3 MODEL DIAGRAM

8M087.113

SEPTEMBER 1984

FIGURE IV.4

HKM ASSOCIATES
ENGINEERS — PLANNERS

Table IV.10

HISTORIC END-OF-MONTH STORAGE

FILE -- 0604950A
SITE -- MIDDLE CREEK RESERVOIR
UNIT -- AC-FT
NOTE -- ANY MONTH WITH ####### INDICATES NO DATA AVAILABLE

02/13/85

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL MEAN
1952	2520	2270	2120	2600	2600	2570	3290	4470	5270	4760	3730	2940	3261
1953	2820	3190	3750	4100	4710	4980	5480	5680	5440	4470	1480	1150	3937
1954	1240	1640	2320	2640	3300	4250	4760	6440	6520	5200	2470	2420	3600
1955	2410	2600	3430	4230	4710	5190	5640	5940	6540	5530	2100	1730	4170
1956	1690	1820	2560	3030	3350	3670	4510	5760	6180	3420	1320	1150	3205
1957	1170	1870	2450	2840	3110	3430	3700	5840	7660	6700	3620	3480	3822
1958	3420	3440	3470	3490	3690	3960	4520	7660	7660	6700	4470	3790	4688
1959	3370	3670	3930	4160	4200	4310	4890	6880	7660	6880	3600	3420	4747
1960	3540	3540	3770	3960	4220	4430	5350	6880	7860	5000	2400	1920	4405
1961	1970	2350	2870	3190	3490	3830	4520	7470	7200	3490	1640	1370	3615
1962	1530	1730	1980	2300	2510	2720	4400	7270	7920	7920	5300	4540	4176
1963	4060	4130	4140	4320	4730	5140	5280	8030	7970	5910	3000	2360	4922
1964	2470	2670	2770	2890	3010	3290	5050	7170	7970	6890	3360	2890	4202
1965	3000	3110	3460	3760	3930	3990	4130	5130	7790	7470	4610	1160	4295
1966	391	819	1170	1360	1780	2350	3290	8240	7970	4840	2150	1560	2993
1967	1150	1360	2060	2600	3000	3480	3920	6620	7990	7580	3670	2740	3847
1968	3060	3100	3120	3340	3330	3360	3470	6880	7970	7620	6000	5400	4720
1969	4450	2900	2970	3480	3800	4030	5180	7820	8080	7330	4250	3470	4813
1970	3150	3140	3370	3770	4100	4400	4430	5400	7860	7350	4950	3700	4635
1971	3150	2970	3410	3990	4510	4820	3840	5010	7720	6940	3370	2570	4358
1972	2320	2350	2730	3310	3740	4280	4880	7760	8040	6960	3210	2490	4339
1973	2400	2450	2500	2540	3030	4160	4620	7390	7970	5840	3530	2750	4098
1974	2900	2980	3210	3910	4360	4400	4200	4470	7470	6840	5360	4720	4568
1975	3170	3210	3110	3570	3880	4230	3400	3340	7020	7600	4470	3360	4196
1976	2850	2750	3310	3650	3870	4070	4560	6360	7800	6670	4080	3480	4454
1977	2970	2520	2700	3150	3690	4690	6740	7890	7960	6180	3170	2950	4550
1978	2970	2970	3310	3650	3930	4240	4570	7170	7920	7640	5010	4180	4796
1979	3530	3310	3310	3470	3440	3730	3780	7350	7990	6100	3820	3170	4416
1980	2740	2710	2790	2950	3170	3530	4390	7360	8030	6530	4070	3620	4324
1981	3310	3300	3460	3770	4070	4370	5320	7560	7850	6240	3540	2910	4641
1982	2890	2950	3660	3560	3800	3820	4160	6550	7660	7760	5690	4400	4741
MEAN	2664	2703	3006	3341	3646	3990	4524	6573	7514	6334	3659	2960	4243
S.D.	898	723	652	658	683	688	772	1205	751	1230	1220	1095	501
COEF. VAR.	.337	.267	.217	.197	.187	.172	.170	.183	.099	.194	.333	.369	.118
PERCENT OF ANNUAL MEAN	5.2%	5.3%	5.9%	6.6%	7.2%	7.8%	8.9%	12.9%	14.8%	12.4%	7.2%	5.8%	

SUM OF MONTHLY MEANS 50,921.9

3. September - April flows reflect the increase in direct flow demand to the City of Bozeman approved during 1984.
4. May - June flows were limited to the estimated downstream direct flow requirement (see Storage Flow Model section).

A table of end-of-month reservoir pool volumes is presented in Table IV.11.

WATER QUALITY

Hyalite Creek has good quality water at the monitoring site located at the parking loop near the Middle Creek ditch diversion and a short distance below the USGS stream gaging station. It appears that the water met the former A-Open (now named A-1) Montana Water Quality Standards for the parameters analyzed on the sample dates.

Recorded water temperatures have been 60°F or less, turbidity averages 4.4 NTU (range 0 to 43 NTU), specific conductance averages 122 micromhos (range 62 to 210), pH is about eight units (range 7.1 to 8.6) and alkalinity averages 61 mg/l. Nitrate nitrogen (as N) averages 0.02 mg/l (range .00 to .13) and phosphate phosphorus (as P) averages .06 mg/l (range .04 to .12) which indicated management activities have had no effect on stream nutrients and also that algae blooms should not occur.

Suspended sediment concentrations average 11 mg/l (range 1 to 51) and sediment yields average 6.2 tons per day (range 0.3 to 32). These are considered to be low amounts, especially since some of the most erosive soils are located below the reservoir.

The water is considered to be soft (hardness under 75 to 150 mg/l) during fall-winter months. Sodium concentrations are very low, averaging only 2.5 milligrams per liter (range 1.1 to 5.2 mg/l).

Table IV.11

FUTURE END-OF-MONTH CONTENTS

FILE -- EOMFUT3
SITE -- MIDDLE CREEK RESERVOIR
UNIT -- AF
NOTE -- ANY MONTH WITH ####### INDICATES NO DATA AVAILABLE

02/28/85

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL MEAN
1952	4229	4034	3839	4124	3929	3734	4259	8071	10310	9605	8380	7395	5992
1953	7200	7274	7355	7360	7600	7551	7856	9402	10310	9145	5960	5435	7704
1954	5330	5535	5845	5650	5759	6096	6411	8867	10310	8795	5870	5625	6674
1955	5430	5421	5803	5915	5803	5703	5859	8663	10310	9105	5480	4915	6534
1956	4720	4655	4828	4821	4626	4626	5271	8445	10310	7355	5060	4695	5794
1957	4520	4703	4848	4702	4507	4503	4578	8189	10310	9155	5880	5545	5953
1958	5350	5175	5010	4835	4774	4743	5108	8385	10310	9155	6730	5955	6295
1959	5660	5765	5830	5965	5684	5539	5934	8709	10310	9335	5860	5485	6673
1960	5410	5215	5250	5245	5310	5325	6050	8734	10310	7255	4460	3785	6029
1961	3640	3825	3691	3496	3379	3375	3870	8319	8124	4266	2416	2146	4212
1962	2306	2506	2756	2922	3068	3273	4958	8330	10310	10115	7300	6345	5349
1963	6150	6025	5840	5925	5944	6153	6104	8754	10310	8055	4950	4115	6519
1964	4030	4035	3834	3699	3504	3318	4716	8240	10310	9035	5310	4545	5394
1965	4560	4475	4630	4735	4710	4575	4520	8163	10310	9795	6740	3095	5859
1966	2900	3133	3239	3284	3392	3570	4315	8092	10310	6985	4100	3315	4723
1967	3120	3135	3462	3517	3422	3516	3761	7387	10310	9705	5600	4475	5159
1968	4600	4445	4270	4295	4100	3935	3850	7920	10310	9765	7950	7155	6049
1969	6960	6765	6640	6955	7005	7040	7995	9453	10310	9365	6090	5115	7474
1970	4920	4725	4760	4963	5098	5203	5038	8359	10310	9641	7046	5501	6305
1971	5406	5211	5456	5655	5980	6095	5900	8678	10310	9335	5570	4575	6514
1972	4380	4215	4390	4561	4709	5054	5459	8515	10310	9035	5090	4175	5824
1973	3980	3835	3690	3535	3379	3780	3964	7962	10310	7985	5430	4505	5200
1974	4460	4345	4380	4850	4862	4707	4512	8165	10310	9485	7810	6975	6238
1975	6730	6625	6430	6695	6810	6965	6770	9000	10310	10310	6985	5680	7446
1976	5485	5290	5655	5800	5811	5796	6031	8749	10310	8985	6200	5405	6631
1977	5210	5015	5000	5017	4851	4656	6006	8718	10310	8335	5130	4715	6080
1978	4540	4345	4490	4624	4709	4824	4959	8330	10310	9835	7010	5985	6153
1979	5790	5595	5400	5365	5170	5265	5120	8390	10310	8225	5750	4905	6273
1980	4710	4515	4400	4365	4390	4497	5152	8405	10310	8615	5950	5315	5897
1981	5120	4925	4890	5005	4903	4915	5670	8593	10310	8505	5610	4785	6102
1982	4590	4455	4622	4427	4472	4297	4442	8139	10310	10215	7950	6465	6198
MEAN	4886	4813	4859	4906	4892	4925	5308	8472	10239	8854	5991	5104	5104
S.D.	1100	1051	1031	1065	1120	1130	1070	384	392	1200	1244	1160	739
COEF. VAR.	.225	.218	.212	.217	.229	.229	.201	.045	.038	.135	.207	.227	.121
PERCENT OF ANNUAL MEAN	6.7%	6.6%	6.6%	6.7%	6.7%	6.7%	7.2%	11.6%	14.0%	12.1%	8.2%	7.0%	

SUM OF MONTHLY MEANS 73,254.4

Bacteria samples collected by Montana State University researchers in 1973 show geometric means of two fecal coliforms and two fecal streptococcus bacteria per 100 ml. Results in 1974 were the same. These are very low levels and it appears that Montana's A-1 fecal coliform standard of 50 bacteria per 100 ml. as a geometric mean has been easily met.

CHAPTER V
DRAINAGE

GEOLOGY AND WATER TABLE

The service area of Middle Creek Reservoir lies on Quaternary alluvial fan deposits that extend from the Gallatin Mountain foothills north, approximately to Interstate Highway 94. These deposits are deep to bedrock, with more than 100 feet of coarse alluvial materials over bedrock in places. The fan material is in turn overlain by a mantle of loess.

The Bozeman fan is recharged by snowmelt, numerous mountain streams that lose all or most of their flow into the fans, and losses from irrigation. It has been estimated by the U.S. Geological Survey (Geological Survey Water Supply Paper 1482) that at least half of the irrigation water applied is added to the water table through deep percolation.

The massive primarily natural recharge into this fan has resulted in the water table to be within five feet of the surface over much of the area.

IRRIGATION PRACTICES

Irrigation has been practiced on the Bozeman fan for many decades. Experience has shown that certain soil series tend to drain more slowly than others. The Huffine and Larimer series, and some phases of the Bozeman series tend to be relatively poorly drained. Cropping patterns over the years have come to reflect the realities of the soils and water table conditions. Deep rooted crops, such as alfalfa, are not grown on the soils with high water tables.

Lands have historically not passed out of production to any degree because of drainage problems. High water tables or poorly drained soils are seldom so serious to precede shallow rooted crops such as grass pasture and small grains, and cropping patterns have been adjusted accordingly.

DRAINAGE CONSIDERATIONS

While much of the Bozeman fan has a water table within five feet of the surface, the massive, natural recharge would render all but the most localized drainage system practically impossible from an economic standpoint.

The problem has been essentially solved by the operators, in a cost effective manner, by adjusting their cropping patterns. Utilization of the poorer drained areas for pasture is valid in an area that is climatically limited to relatively low value crops and which is heavily dependent upon livestock enterprises. HKM proposes no new cropping pattern for the service area, but instead would continue the practices that have been historically successful.

In summary, while all lands are not suitable for deep rooted crops, artificial drainage of these lands would be most difficult and probably not economically justifiable.

CHAPTER VI
PLAN OF DEVELOPMENT

PHYSICAL PLAN

The selection of a plan for Rehabilitation of Middle Creek Dam was dictated by the requirement that the structure have the capacity to pass the Probable Maximum Flood (PMF) without failure. Although the dam would not fail, the auxiliary spillway system may experience considerable damage. Since the rest of the creek channel would experience similar damage and the frequency or risk of this level of flooding is very low, damage in the auxiliary spillway is considered acceptable.

The more frequently occurring floods must be passed without damage through a principal spillway system designed for this purpose. The 500-year flood was chosen for the design flowrate of the principal spillway system. This frequency of flooding was chosen in lieu of the more commonly accepted 100-year frequency for the following reasons:

1. This choice greatly reduces the chance that the auxiliary spillway will operate with its associated damage.

2. The existing spillway will accommodate the 500-year flood with very little modification and the additional cost of the lower drop structure is not significantly increased.

3. The difference between the 100-year flood (700 cfs) and the 500-year flood (1,000 cfs) is not significant.

4. The margin of safety provided will encourage the MCWUA to regulate the outlet works to insure that the reservoir fills each spring.

These criteria led to a design incorporating two major features. The first feature includes the excavation of a large auxiliary spillway on the left (west) abutment. The excavated material will be placed on top of the dam embankment, raising the crest elevation by 10 feet and providing the necessary freeboard during the PMF. In addition, the storage of the reservoir will be increased by 2,334 AF which can be utilized for irrigation and municipal use. The second feature of the physical plan is the rehabilitation of the existing principal spillway to provide adequate hydraulic capacity for passing the 500-year flood without significant damage. The major features are shown in the site plan (Exhibit No. A-1) found in Appendix A.

GEOTECHNICAL INVESTIGATION

A field drilling program and geotechnical investigation was conducted during the fall and winter of 1983. The details of this study are reported in Middle Creek Dam, Geotechnical Investigation, dated April 1984, HKM Associates, and the results are summarized in the following paragraphs.

The purpose of this geotechnical investigation was to provide an understanding of the physical conditions on which to evaluate rehabilitation alternatives for this facility.

"As built" drawings of the project are not available. Design drawings are on file at the DNRC in Helena, Montana. There was no stability analysis of the embankment previous to this investigation. No instrumentation, such as piezometers and survey control points, had been established at the facility prior to this study.

General Approach

The general approach began with a subsurface soils investigation to determine the physical and engineering

properties of the materials. Subsequently, representative soil samples were selected for laboratory testing and engineering analyses were performed. The findings of these field and laboratory investigations and the engineering analyses were used as the basis for rehabilitation alternative selection and evaluation.

The field investigation included making 15 exploration drill holes and 14 test pits to determine soil conditions and obtain samples for laboratory testing. Instrumentation, to monitor embankment movements and changes in ground water levels, was installed during the field investigation. A geologic investigation was made to assist in evaluating the soils and the impact of a seismic event on the structure. The engineering analyses included seepage and stability studies. Both static and dynamic stability analyses were also performed.

Findings of Condition of Existing Dam

As recommended in the Dam Safety Report, stability of the existing structure was analyzed. The results of this investigation are reported in detail in the Middle Creek Dam Geotechnical Investigation Report. The analysis of the enlarged dam can be found in the Design section presented later in this chapter.

Seepage through the left abutment is high but does not create a stability problem with the existing embankment, nor a piping problem through the abutment. Presently, this seepage is being at least partially controlled by the existing drains. The condition of the foundation drain is unknown. An increase in the embankment crest elevation will require preserving and lengthening the existing drain system.

Seepage through the embankment and its foundation and through the right abutment does not appear to be a problem. Ground water levels and seepage throughout the downstream area should continue to be monitored. If the embankment and pool elevations are increased, a monitoring system should be constructed to record the drain discharge. Presently, a critical flow flume has been installed to measure discharge from the left abutment drain. It is recommended that the seepage from both abutments be monitored.

The results of the static stability analysis indicate the factors of safety for the existing structure are within the Recommended Guidelines.[1/] Transition to the results of the dynamic stability analysis indicates that the minimum factor of safety against liquefaction is 1.5. These results are based on a maximum earthquake (design earthquake) of 6.5 (Richter Magnitude) at a distance of 25 kilometers from the dam with a horizontal acceleration of 0.22g at the base of the structure.

Deformation resulting from the design earthquake is calculated to range from 0.4 to 1.0 foot. This amount is relatively small compared to the available freeboard and is not considered a problem.

DESIGN

The project plan has three major features: construction of an earthen auxiliary spillway, raising of the dam structure, and rehabilitation of the existing principal spillway. These actions will allow the dam structure to meet dam safety criteria for passage of probable maximum flood flows while minimizing the cost of repair and/or facility additions. This has been achieved by using the existing structure wherever possible.

[1/] Recommended Guidelines for Inspection of Dams.

Design Rationale

There were two levels of concern in this preliminary design which influenced the selection of design criteria. First, the principal spillway has been redesigned so that it can accommodate the routed 500-year flood without damage. Secondly, the principal and auxiliary spillways must be capable of safely passing the PMF without overtopping the dam. Use of the PMF was dictated by the large size of the dam and the expected consequences of failure including possible loss of life and the potential for extensive economic losses.

Auxiliary spillway design criteria is dictated by present standards which require that the public safety be insured. These criteria have been set because of dam failures in the past.

Alternatives Considered

In the planning process, many alternatives were considered. The following discussion summarizes the results of these studies out of which the recommended plan evolved.

Three levels of increase in dam height were examined; no increase, a 5-foot increase and a 10-foot increase. The dam height increases allowed better utilization of the natural topography in the left abutment area for an auxiliary spillway. Two alternatives were examined for raising the dam; reinforced earth and placing embankment on the downstream side. Reinforced earth was chosen on the basis of lesser cost, reduced loading on the existing embankment (less settlement) and conduit, better performance during earthquake loading and a reduced construction time.

Concerning the auxiliary spillway, two locations were considered; the right abutment in the vicinity of the existing spillway and in a natural drainage in the left abutment. The left abutment was chosen because the natural topography would accommodate large flows without endangering the dam embankment. To contain these same flows in the right abutment would require expensive structural measures and would occupy the same space as the principal spillway.

The configuration of the auxiliary spillway located in the left abutment is dependent upon the height of the dam. The no-increase configuration is shown on the alternative site plan sheet, Exhibit A-2, Appendix A. This spillway is much wider and deeper when compared to the spillway shown on the recommended general site plan, Exhibit A-1, Appendix A (10-foot increase in dam height). In all alternatives a training dike and excavation is necessary in the lower portion of the spillway channel to prevent flood waters from eroding the embankment.

Many alternatives were considered for the principal spillway rehabilitation. The spillway system was analyzed in two locations; the existing structure and a new structure to make the final drop to Hyalite Creek. Alternatives for the existing structure are listed as follows:

1. Demolish the old spillway and replace it with a new structure.

2. Provide a new spillway in a different location such as the right abutment - embankment contact or an "on-dam" structure (would solve both upper and lower problems).

3. Place a new structure within the walls of the existing structure and replace the stilling basin.

4. Automate outlet works releases as the existing conduit has the capacity to pass 500-year flood flows (serves both existing and lower structure design goals).

5. Repair the existing spillway given no increase in dam height to pass 500-year flood flows.

Alternatives considered for the new, final drop structure are listed as follows:

1. Stabilize the natural channel with drop structures constructed of timber, concrete, gabions, rocks or other materials.

2. Direct flows to a concrete chute located just below the dam on the right abutment.

3. Dike off flows to left near end of channel exit to Hyalite Creek and allow channel to erode, eventually armoring the channel with natural rock.

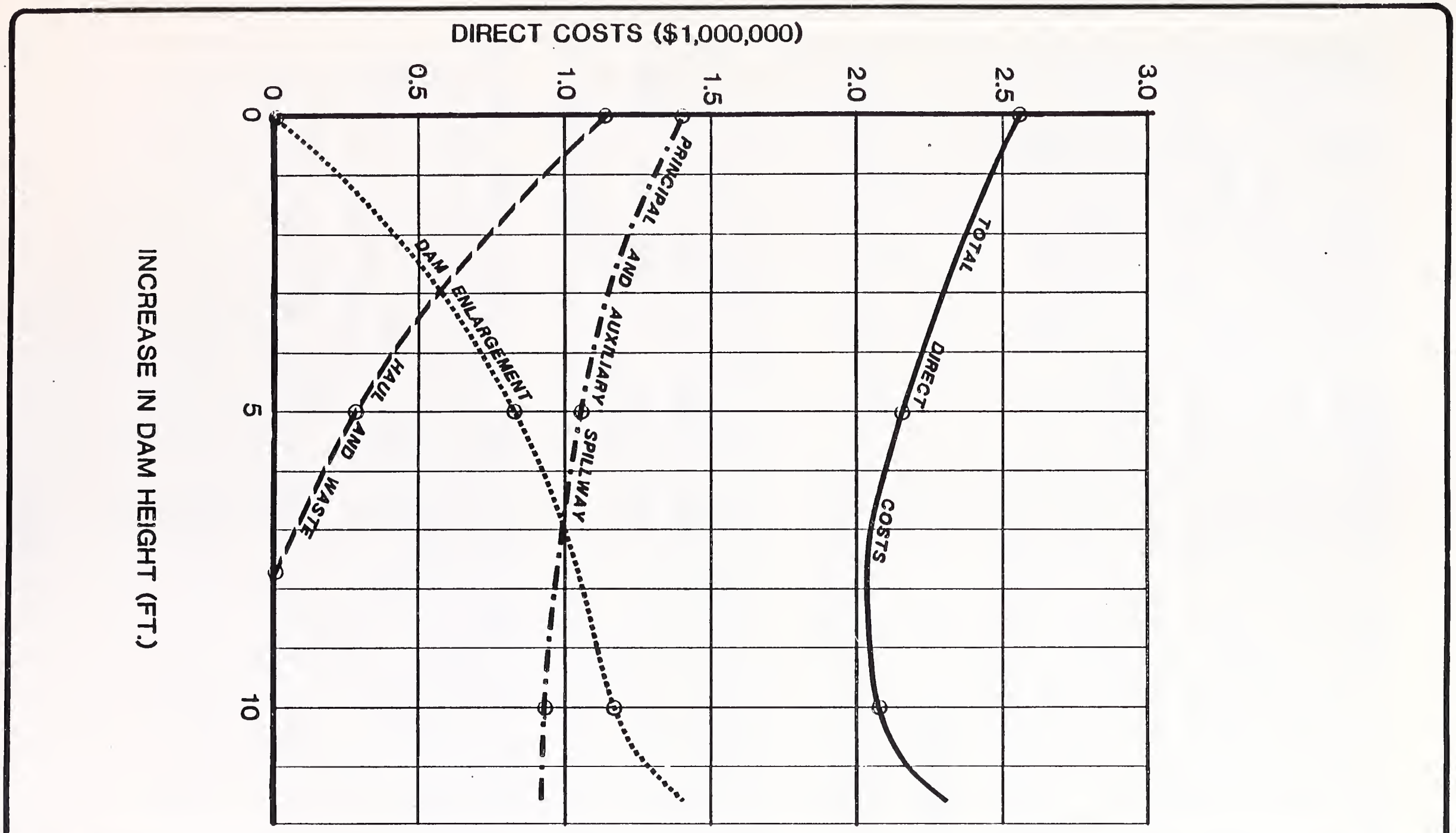
4. Continue operating reservoir at reduced levels to minimize use of the spillway.

The "on-dam" structure concept was discounted without detailed study because of potential problems. If at all possible, placement of the spillway over an embankment should be avoided because of the higher potential for damage and possible failure due to piping along the outside surface of the concrete structure, settlement of the embankment, the differential response of the embankment and spillway during earthquakes. Automation of the outlet works is an economical solution but is not foolproof as mechanical equipment would be necessary. Demolition of the old spillway structure would be relatively expensive, and a totally new structure would add additional

cost. Erosion of the spillway channel is considered unacceptable from an engineering and environmental standpoint. Access, maintenance and cost were considerations for the gabions or similar weir drop structures.

The life of gabions or timber structures is questionable. Given these considerations, the recommended alternative is placing a new structure inside the old spillway for the upper area and diverting flows to a baffled apron drop just downstream of the right abutment for the lower part of the system. The recommended alternatives are discussed in greater detail in the following paragraphs.

The most economical combination of alternatives is a function of dam height. If the dam is not increased in height, the auxiliary spillway must be wider and deeper to pass the PMF with adequate freeboard on the dam. This results in increased excavation and haul to waste which substantially increases costs. Until an earthwork balance is achieved between material excavated and material used in the dam enlargement, there is a significant cost with waste of the excess material. Three dam heights were examined on a reconnaissance basis. As shown in Figure VI.1, the economic minimum occurs with a 8- to 9-foot increase in height. A 10-foot increase was chosen as a recommended alternative as: 1) the City of Bozeman will need the additional water, 2) this amount of additional water is available from the watershed, 3) the reinforced earth alternative may become questionable with a height greater than 10 feet, and 4) 10 feet is the limit of increase without impacting existing facilities and project costs.



MIDDLE CREEK DAM REHABILITATION

DIRECT COSTS vs. DAM HEIGHT CURVES

8M087.113

SEPTEMBER 1984

FIGURE VI.1

HKM ASSOCIATES
ENGINEERS — PLANNERS

An alternative to optimize environmental conditions was also considered. This plan would not differ physically from the preferred alternative previously stated. However, the water surface in the reservoir would be held at the historical level at the top of flashboards (8,267 AF of active storage). The remaining storage would be flood surcharge (1,917 AF) and would be released as quickly as possible after it was filled. This operational plan would minimize environmental concerns with the increase in water levels. However, this alternative has the serious disadvantage of not providing additional water to finance the dam safety improvements.

Auxiliary Spillway

The proposed auxiliary spillway is located on the left abutment of the dam as shown in Exhibit A-1.

The peak design flow is 29,000 cfs for the auxiliary spillway, which is the maximum auxiliary spillway flow during the routed PMF. Should a PMF occur, channel velocities greater than 23 feet per second (fps) will be experienced. Considerable damage and erosion will occur if this spillway operates, but the damage would be minor compared to that caused by a dam breach.

Velocities across the crest during PMF approach 10 fps, which can be expected to cause significant erosion. The presence of numerous large rocks and boulders in the soil beneath the crest would inhibit erosion after a short time. This natural armoring process, combined with the infrequent use of the spillway (recurrence greater than 500 years), should alleviate the need of a concrete sill at the crest of the auxiliary spillway.

The auxiliary spillway proposed will have a circular crest (in plan) having a 530-foot arc length and horizontal radius of curvature of 494.5 feet. A 460-foot transition follows, which narrows the channel bottom arc length from 530 to 37 feet on a slope of 4.17%. Beyond the transition to a point immediately beyond the existing main access road, the channel has a bottom width of 37 feet and a slope of 0.22%. All side slopes perpendicular to the centerline of the auxiliary spillway are 2.5H:1V. Flow from this excavation spills over the existing main access road into the depressed area below. Water then flows through a 130 foot wide excavation until reaching the steep slope down to Hyalite Creek. In addition, a small dike along the right side of the channel keeps water away from the toe of the dam. The main access road to the reservoir is directed up the auxiliary spillway to the crest, where it branches either left to the dam crest or right to the campground.

The plan and profile for the auxiliary spillway are shown in Exhibits A-1 and A-7. Hydraulic computations are described in Exhibit E.

Dam Enlargement

The storage capacity of Hyalite reservoir will be increased by enlarging the Middle Creek Dam embankment. To provide additional storage and to pass the Probable Maximum Flood, the crest will be raised approximately 10 feet, to elevation 6,732.0 feet NGVD.

The embankment will be raised using a combination of construction methods consisting of reinforced earth and conventional earthfill as detailed on Exhibit A-8. The reinforced earth construction method is used on the crest of

the existing embankment where the embankment is high. The reinforced earth provides the following primary advantages over the conventional earthfill:

- It costs less than the conventional earthfill method.

- The reinforced earth adds some weight to existing fill but significantly less than conventional fill. This is an advantage because it will reduce additional settlement.

- The reinforced earth technique requires less fill. It allows a balance between the cut and fill volumes.

- The reinforced earth construction can be completed in one construction season.

The volume of excavation from the auxiliary spillway is 83,800 CY, a portion of which will be used to raise the dam crest elevation to 6,732.0 feet NGVD through the use of both reinforced earth and conventional fill. The reinforced earth portion will require approximately 16,000 CY fill to provide a crest elevation of 6,732.0 feet NGVD. The conventional fill portion of the dam crest will be at elevation 6,732.2 feet NGVD and will require 30,000 CY with the parking lot on the east end. The dam crest elevation selected will provide 2.1 feet of freeboard on the reinforced earth portion and 2.3 feet of freeboard on the conventional fill portion at the maximum water surface elevation during the PMF. The additional 0.2 feet of freeboard on the conventional fill portion is necessary to accommodate wave runup, which is not a factor on the vertical face of the reinforced earth section with a wave deflector. In addition to the dam fill, the training dike at the downstream end of the auxiliary spillway requires 4,600 CY of additional

borrow material. Approximately 2,000 CY will be used to reclaim the road near the left abutment area. Approximately 2,000 CY will be used to construct the road to the Edsall cabin.

Of the 83,800 CY excavated in the auxiliary spillway approximately 15% is expected to be waste due to cobbles and boulders. This material will be used as riprap or placed on the east side of the dam near the principal spillway to construct a parking area. A shrinkage factor of 10% is expected as the excavated material is placed in compacted fill. This yields 63,000 CY of material. Approximately 56,600 CY will be used for embankment and road base material as described above. The remaining 6,250 CY will be consumed in the processing of drain fill and road surface coarse material. The excavation and fill requirements are approximately balanced.

Static Stability

Stability of the reinforced earth portion was evaluated. Conditions of static loading were imposed by the additional weight on the embankment from the retaining structure and by the higher reservoir water surfaces against the embankment and retaining structure. Evaluations of embankment stability for steady-state seepage and reservoir drawdown were completed.

Stability computations for the existing embankment and the modified embankment section with the reinforced earth under steady-state seepage and rapid reservoir drawdown were made using appropriate static stability methods. The results of embankment static stability computations are shown in Table VI.1.

Table VI.1
Results of Embankment Static Stability Analysis

Condition	Critical Failure Surface	Safety Factors (calc.)	(recom.)
Existing embankment			
Steady-State Seepage	Downstream-Circular	1.7	1.5
Rapid Drawdown	Upstream-Circular	1.3	1.2
Modified Embankment with Reinforced Earth			
Steady-State Seepage	Downstream-Circular	1.6	1.5
Rapid Drawdown	Upstream-Circular	1.2	1.2

These results show that the additional load from the retaining wall system and higher reservoir water surfaces has only minor effect on the embankment stability. The computed minimum factors of safety are within acceptable limits for these conditions. A dynamic analysis was not performed as the analysis of the existing structure demonstrated this factor was not critical.

Stability of the earthfill portion of the embankment is essentially the same as the minimum safety factors listed above for the existing embankment. Stability for the earthfill portion of the embankment is not a problem.

Seepage Control

The reinforced earth system must provide a relatively watertight barrier and assurance that seepage during high reservoir levels would not affect stability. Flood routing studies showed that the reservoir water surface could be above the normal water surface elevation for as long as 3 weeks

during a snowmelt flood event. Therefore, the structure must be capable of providing the necessary protection against seepage that could affect the integrity of the structure or embankment.

A viable means of providing a water barrier is to seal all joints on the upstream retaining structure wall. This will be accomplished by applying a waterproof flexible membrane over the joints on the inside face of the wall, as shown on Exhibit A-8. Assurance of a continuous membrane-to-wall seal would be difficult to control during construction. Therefore, as a defensive design measure, it is necessary to provide zoning of materials within the reinforced earth section to further control any seepage not stopped by the membrane. This is accomplished by using the compacted sand and the gravel drain with a seepage collection pipe as shown in Exhibit A-8.

To maintain stability with an increase of 10 feet in the pool elevation, the phreatic surface must be maintained at near the elevation of the existing phreatic surface. This will be accomplished by constructing an impervious barrier trench with a collector drain at the bottom of the trench as shown on Exhibit A-8. The barrier trench will have an impervious fabricated membrane (equivalent to Hypalon) to provide a positive barrier.

Two manholes will be located along the seepage barrier trench to allow monitoring and maintenance.

Principal Spillway

The existing spillway for Middle Creek Dam discharges water into a tributary of Hyalite Creek approximately 85 feet above the Hyalite Creek channel. Passage of spillway discharges has caused significant erosion in the downstream portion of this

tributary. The spillway, though large enough to carry the 500-year flow, has experienced severe weathering damage. In its present condition, a large flow could cause severe damage.

The proposed principal spillway rehabilitation will provide for passage of the 500-year flood without damage. The rehabilitation plan for the principal spillway includes construction of a new spillway within the old spillway, an earth channel leading from the discharge area of the existing spillway to a point on the slope above Hyalite Creek, and a baffled apron drop to Hyalite Creek. Exhibits A-1 to A-6 show the general details of the key features established above. The design of each feature will be discussed below.

Inlet Crest. An elevated labyrinth weir with sloping upstream face will be placed on the upstream side of the existing ogee crest. The elevation of the crest has been set at 6,721.0 feet NGVD. This is 10.2 feet above the existing ogee crest. The overall length of the crest is 143 feet. Discharge over the crest falls 4 feet to the level apron waterway constructed on consolidated fill. The configuration of the labyrinth is based on studies conducted by Hay and Taylor, ASCE Hydraulics Journal, November 1970. At the design head, the crest coefficient is 3.52. Exhibit A-4 details the weir configuration.

Concrete Chute. The level apron transitions through a vertical curve to point of tangency with the existing chute floor with a slope of 67%. The chute continues at a slope of 67% to an intersection with the basin floor. The walls of the new chute are cast against the floor of the existing chute on the inside of the existing walls. The upper walls will be extended to elevations necessary to satisfy freeboard or top of dam constraints. A prestressed concrete bridge will span the 37-foot chute. The bottom elevation of the bridge is set at

elevation 6,723.3 feet NGVD, which will limit the flow entering the principal spillway during the PMF to 3,400 cfs. This elevation provides a 6.3-foot opening through the spillway that should not be affected by clogging. Exhibit A-4 shows the proposed chute.

Stilling Basin. The existing stilling basin will be demolished as it is in very poor condition. A new U.S. Bureau of Reclamation (USBR) Type III basin will be installed in its place. The basin is suggested for use when the Froude number of the incoming flow is greater than 4.5 and the velocity is less than 60 fps which is the case in this design. The basic features of this basin, shown in Exhibit A-4, include chute blocks, baffle blocks, and an end sill, all of which aid in dissipating energy and shortening the length of basin required. The basin has a length of only 23 feet, while without these features a basin length of over 30 feet would be required. This results in a considerable savings in concrete and cost. Proper operation of the basin is dependent upon the required tailwater depth which, at the design discharge, is 8.4 feet. This depth is a function of the hydraulic characteristics of the outflow channel and the baffled apron drop inlet elevation. Exhibit A-4 shows the proposed stilling basin.

Channel. Immediately beyond the stilling basin, the channel will be widened slightly to lower velocities at the design discharge. A dike across the meadow downstream directs the water into a grassed channel which terminates at the intake of the proposed baffled apron drop. Nonerodible velocities of less than 5 fps are maintained in the grassed channel. The minimum bottom width in the channel is 15 feet, and the side slopes are 2.5H:1V. The meadow dike is designed to overtop for flows greater than the 500-year discharge. The channel banks maintain 3.5 feet of freeboard as recommended by the USBR. Exhibit A-1 details the channel earthwork.

Baffled Apron Drop. A 30-foot-wide baffled apron drop is proposed to convey the 500-year flood without damage to Hyalite Creek, approximately 85 feet below. This type of structure was chosen due to the lack of space for a conventional stilling basin. The crest of the baffled apron drop is located at an elevation which maintains nonerodible velocities in the channel upstream. The required crest elevation is 6,688.7 feet NGVD, which is greater than the channel invert through the meadow (see Exhibit A-3). Drainage of the channel following flood events will be accomplished by natural seepage or installation of a small culvert through the dike. The baffled apron drop is designed with a 2H:1V chute slope. USBR design standards were generally followed. The tailrace of the baffled apron drop is designed to be protected by riprap, which is installed integrally with the low-level outlet protection. The proposed baffled apron drop is shown in Exhibit A-5.

Low-Level Outlet Protection

Serious bank erosion beyond the low-level outlet will be alleviated in the proposed plan. Since the design of the principal spillway will be such that it can be used frequently, the releases through the low-level outlet can be limited to those required for downstream use. The maximum historic monthly outflow was 300 cfs (July 1975). The outflows will be limited to this value. The exit velocity in the conduit flowing full at 300 cfs is 13.4 fps. At this velocity it is doubtful that the flow will uniformly expand in the outlet transition. It is assumed that local velocities near the bottom of the outlet transition can be 13.4 fps. A short section of 27-inch nominal riprap will stabilize the bottom and banks until the flow has had a chance to expand. The left bank will be cut back to a stable 2H:1V slope. Riprap protection of the banks along both sides of the outlet channel to a point

where the flow expands to uniform conditions completes the outlet protection measures. The proposed outlet protection is shown in Exhibit A-1.

Effect of Increased Water Levels on Gate House

The top of the gate house walls is presently at elevation 6,724.0 feet NGVD. The water surface elevation during the occurrence of the 500-year flood will be 6,722.6 feet NGVD or 1.4 feet below the top of wall elevation. This is less than the minimum required freeboard of 2.1 feet so small amounts of water can be expected to splash onto the structure. During the PMF, the water surface will be 5.9 feet above the walls and may cause limited damage. Following large, infrequent, flood events, the gate house can be pumped dry with the existing jet pump at the base of the tower. The risk of the damage from extreme flood events is not great enough to warrant raising the control tower and gate house.

RIGHT-OF-WAY AND LAND ACQUISITION

Enlargement of the dam and reservoir will result in an increase in both normal water surface and maximum flood pool elevations.

Several parcels of land will be impacted by the proposed project in a number of ways (see Figure VI.2). An auxiliary spillway is planned on the left abutment and impacts the existing Blackmore Campground. The proposed plan is to increase the dam crest and permanent reservoir pool elevation.

MIDDLE CREEK DAM REHABILITATION

FIGURE

Middle Creek Dam and Reservoir are located on three sections of land in Township 4S Range 6E. Project lines in Section 15 and 22 are on national forest lands and operate under a Forest Service special use permit. Section 23 is managed by the Forest Service with the exception of the following land areas:

1. State purchased 66.05 acres from William S. Bole.
2. Hyalite Junior Camp (5.8 acres) belonging to Gallatin County.
3. A 0.73-acre cabin site tract belonging to Wayne Edsall in the NW1/4, SW1/4.

These existing land rights are all affected in some degree by the rehabilitation of the dam. The effects are caused by proposed actions to build an auxiliary spillway in the left abutment area, to increase reservoir storage and surface area by raising the dam. Existing land right agreements will need to be modified in a variety of ways to accommodate the proposed modifications.

Blackmore Campground. Blackmore Campground is a small facility located in the southwest quarter of Section 15, Township 4S Range 6E. It is located immediately south of the southwest abutment of the dam at an elevation just a few feet above the permanent flood pool of the reservoir. This is the proposed site for the auxiliary spillway. Brush and trees are to be removed from the area and after construction is finished, reseeded to grasses. The campground will be re-established at a location north of the dam in the general location as shown on Figure VI.2.

Hood Creek Campground. Hood Creek Campground is along the northern shore of the lake in Sections 15 and 16. This facility is designed for overnight as well as day use. Most

facilities are high above the existing reservoir except for the boat ramp, the boat trailer parking area, and a few picnic tables on the upstream end.

An extension of the boat ramp to the higher reservoir level is proposed. The picnic tables in the flood zone will be moved.

Hyalite Junior Camp. Hyalite Junior Camp is a youth camp originally developed and operated by Hyalite Junior Camp Association. The lands for the camp straddle the line between Sections 22 and 23. A portion of the camp in Section 22 has a Forest Service special use permit. The land in Section 23 originally purchased by the association was turned over to Gallatin County.

A 10-foot increase in the permanent pool would not affect structures at the camp, but would inundate additional land. The reservoir side of the camp properties are loosely defined as the high water mark of the reservoir. The portion of the camp in Section 22 may require amendments to the USFS special use permit. The fee land in 23 will require negotiation for land rights with the Gallatin County Commissioners.

SCS Snow Course. The Hood Meadow Snow Course No. 10-D03 is located in the SW4, NW4, Section 23, Township 4S Range 6E. The course has 10 stations located between the roadway and the high permanent pool elevation.

An increase in the permanent pool will, at high stage, inundate many of the stations on the Snow Course. Normally during the snow measuring season, the reservoir elevation is several feet lower than maximum pool and, therefore, would not interfere with the snow measurements. SCS should make the decision whether or not it is required to move the snow course. If

there is a requirement to move the course, SCS officials have indicated that a one- or two-year notice is sufficient for them to re-establish additional points at higher elevations so the records for the two locations can be correlated. The present course is located on state-owned land. However, the U.S. Forest Service at one time issued a special use permit apparently assuming that the land was Forest Service land.

Proposed Chisholm Campground. The site for the proposed Chisholm Campground is in the north half of the southwest quarter of Section 23. The general area is used occasionally for camping, but at present, it is largely unimproved. The majority of the proposed campground lies on state-owned land. The balance is on adjoining U.S. Forest Service land.

The proposed site for the campground would be affected by any option to raise the permanent pool of the reservoir. An option to increase the permanent pool 10 feet would be confined within the State property. The proposed location for the campground should, therefore, be reconsidered for adjacent areas or alternate configurations to match the new proposed reservoir.

Edsall Cabin. The cabin site owned by Wayne Edsall lies in the NW4, SW4 Section 23, Township 4S Range 6E and contains 0.73 acres. The northeast corner of the property appears to coincide with the state boundary around the reservoir.

A small portion of the property would be inundated by a 10-foot increased permanent pool. Negotiations with the property owner will probably be required. A new access road will be constructed as shown in Figure VI.2 as well. The existing bridge will be moved upstream.

ACCESS ROADS

Traffic During Construction

During construction of the reinforced earth section, traffic will be detoured onto a single lane roadway located on the downstream face of the dam. The proposed cross section is shown on Exhibit A-8 in Appendix A. This roadway will have a gravel surface, a steel and wood post guardrail on the downslope side and a woven wire fence between the reinforced earth and the roadway. Traffic will be controlled during the construction season by flagpersons stationed on each end. This roadway will then continue on the embankment section and connect to the main road on a berm located in front of the principal spillway (see Exhibit A-1). This detour will serve as the primary method of routing traffic through the construction area.

Left Abutment Main Road

The main road leading to the left abutment will be rerouted through the auxiliary spillway as shown in Exhibit A-1. This change will allow acceptable grades to the top of the dam; now 10 feet higher. The roadway will have a base course and width suitable for paving. Cross drainage and borrow pits will be provided. This area may require a speed reduction due to line of sight and horizontal curve limitations. A speed reduction would be prudent because of the day use area and traffic stopping to observe the reservoir.

Edsall Cabin Access Road

Presently a causeway and bridge provide access to the Wayne Edsall Cabin, as shown in Figure VI.2. An increase in the permanent pool would inundate this road during certain times of the year. Several alternatives were considered to rectify this

situation. The existing access road could be raised 10 feet throughout its length and the bridge raised 10 feet. This is a very costly alternative due to the amount of earthwork required and the need for riprap protection of the causeway on both sides. Access could be by boat only when the roadway is inundated. The cabin could be purchased and abandoned. The selected solution was to construct a new access road above the high water line but on state land. This route is shown on Figure VI.2. The existing timber bridge would be moved to a new site upstream connecting with this road. If the road should become more expensive to construct than purchase of the cabin, then the latter option should be pursued.

DESIGN SUMMARY

Table VI.2 has been prepared to provide a comparison of the existing situation and the proposed design. All of the pertinent data regarding elevations, excavation and fill volumes, design discharges, and design features are presented. Elevation-area-storage curves are presented in Figure VI.3.

In summary it is proposed to excavate a large auxiliary spillway through the left abutment and raise the dam 10 feet with a combination of reinforced earth and embankment enlargement. The dam crest elevation is such that protection of the structure can be assured during the PMF. The existing principal spillway will be rehabilitated to provide adequate hydraulic capacity for passing the 500-year flood. This will require a new inlet crest, a new chute with increased wall elevations within the existing chute, replacement of the stilling basin, modification of the outflow channel, and a new baffled apron drop structure. The low level outlet releases will be limited to the maximum anticipated conservation releases to minimize streambed protection measures required in the discharge area.

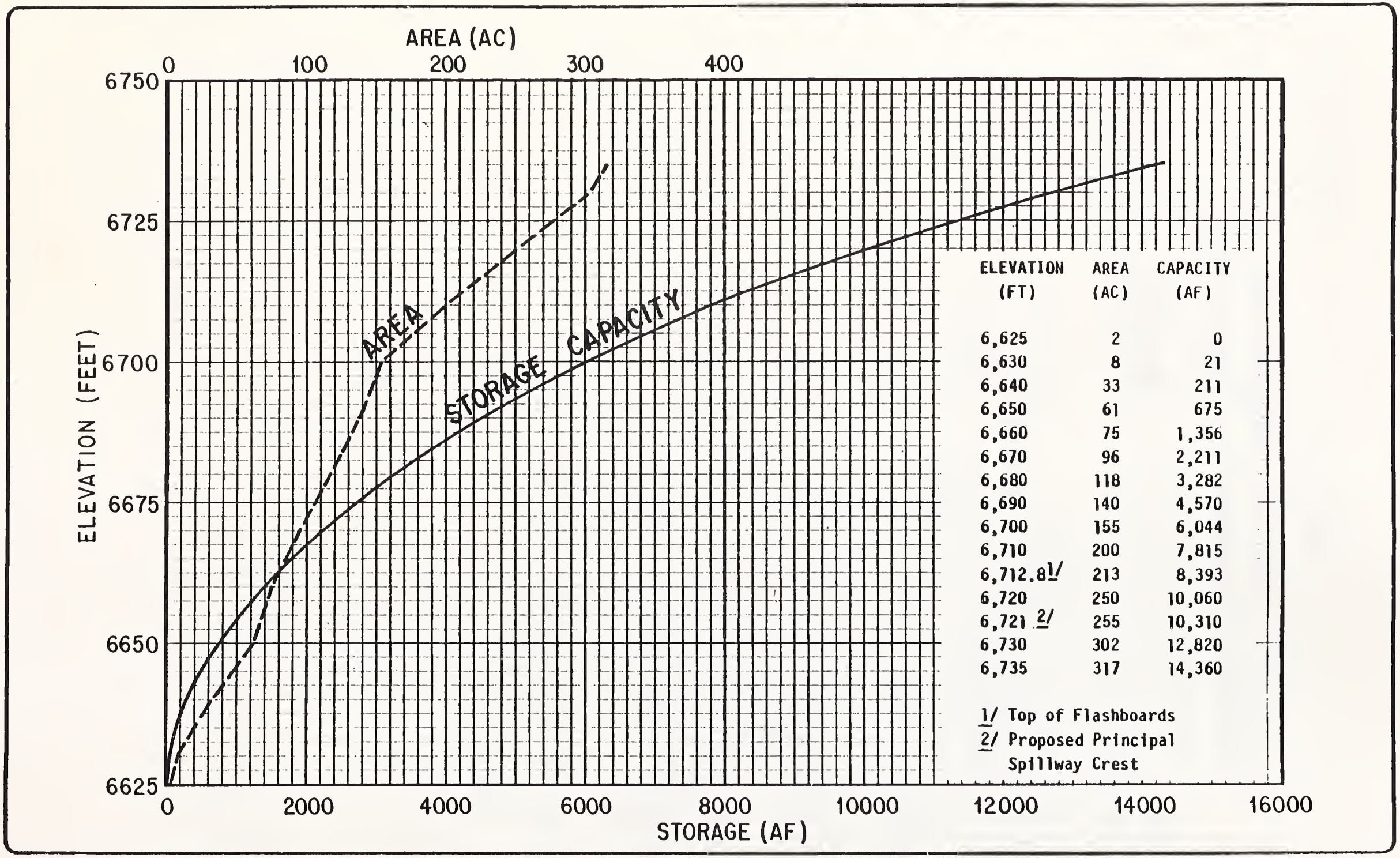
Table VI.2

MIDDLE CREEK DAM AND RESERVOIR

PRINCIPAL CHARACTERISTICS SUMMARY TABLE

Parameter	Existing	Proposed
Structural Height (ft)	117	127
Dam Crest Elevation (ft NGVD)	6,722.0	6,732.0
Normal Water Surface Elev. (ft NGVD)		
(Without Flashboards)	6,710.8	6,721.0
(With Flashboards)	6,712.8	
Active Storage Capacity (AF), 1984		
(Without Flashboards)	7,850	10,184
(With Flashboards)	8,267	
Total Storage Capacity (AF), 1984		
(Without Flashboards)	7,976	10,310
(With Flashboard)	8,393	
500 Yr. Peak Outflow (cfs)		
(Without Flashboards)	1,000	1,000
100 Yr. Peak Outflow (cfs)		
(Without Flashboards)	740	740
Maximum 500 Yr. W.S. Elev. (ft NGVD)	-----	6,722.6
Maximum 100 Yr. W.S. Elev. (ft NGVD)		
(Without Flashboards)	6,713.8	6,721.6
Spillway Design Flood	3/	PMF 2/
Maximum W.S. Elev. (ft NGVD)	3/	6,729.9
Freeboard at Maximum W.S.	3/	1/

1/ Freeboard on reinforced earth portion is 2.1 ft and on conventional fill is 2.3 ft.
2/ The PMF has a peak discharge of 32,400 cfs.
3/ No information is available on hydrologic investigations used in the design of the original structure.



ELEVATION (FT)	AREA (AC)	CAPACITY (AF)
6,625	2	0
6,630	8	21
6,640	33	211
6,650	61	675
6,660	75	1,356
6,670	96	2,211
6,680	118	3,282
6,690	140	4,570
6,700	155	6,044
6,710	200	7,815
6,712.8 1/	213	8,393
6,720	250	10,060
6,721 2/	255	10,310
6,730	302	12,820
6,735	317	14,360

1/ Top of Flashboards
2/ Proposed Principal Spillway Crest

MIDDLE CREEK DAM REHABILITATION

ELEVATION-AREA-CAPACITY CURVES

8M087.113

SEPTEMBER 1984

FIGURE VI.3

HKM ASSOCIATES
ENGINEERS — PLANNERS

CHAPTER VII
ESTIMATED COSTS

ESTIMATES OF COST

Estimates of cost have been prepared for the construction of the proposed project facilities. They are based on the criteria and general design considerations presented in Chapter VI.

The total estimated capital cost of the project, based on July 1984 cost levels, plus an allowance for projected price increases, is approximately $4.3 million. This estimate includes, in addition to direct construction costs, reasonable allowances for contingencies, investigations, engineering, acquisition of lands, DNRC overhead and legal fees, interest during construction, and lending institution participation. A contingency allowance of 25% has been assumed for this project considering the unknown costs of land acquisition, accommodating environmental issues, strict requirements of the USFS concerning access roads and campgrounds and other unknowns associated with obtaining a special use permit to complete this work. A summary of the estimated capital costs, loan obligation, and DNRC contribution appears in Tables VII.2.a and VII.2.b.

PROJECTED FUTURE COSTS

It is anticipated that contracts for construction of the project will not be awarded before September 1986. On the basis of past history, the cost of construction can be expected to rise above the present level (July 1984). For this reason, an allowance of 15% has been included to accommodate cost

escalation which is expected to occur between the time of preparation of the cost estimate and the award of the construction contract.

LAND ACQUISITION AND RIGHTS-OF-WAY

The dam and most of the reservoir basin is located on United States Forest Service and Montana state land; therefore no land acquisition costs are necessary. There is a private cabin located near the shore on the southwest side of the reservoir. The cabin itself will not be affected by increased water levels but a small portion of the tract on which the cabin stands will be flooded when the reservoir is filled. The PMF will flood additional land but will not reach the cabin floor. This may require a flood easement or outright purchase to be negotiated with the owner of the cabin. Costs to the project have not been determined at this time. It is assumed that these costs will be within the contingency set for this project.

ENGINEERING AND ADMINISTRATION

No contracts for engineering other than the feasibility study have been entered into by DNRC; therefore, these costs are based on estimates. These estimates include surveying, the preparation of plans and specifications, field inspection, supervision of construction, and assistance in placing the facilities in operation. Costs are included for preparing the initial permit applications such as the USFS special use permit and a 404 COE permit. Costs are not included for long, drawn out interchange as commonly occurs.

In addition to the engineering, the DNRC and MCWUA will incur administrative costs consisting of general supervision, environmental assessment coordination, contract negotiations, water rights, and other miscellaneous items involved in this

phase of work. These costs have been included to the extent that they are directly attributable to construction of the project. DNRC and MCWUA will contribute these costs.

The total estimated cost of 14% for engineering and administration has been applied to the construction cost estimates.

ESTIMATED COST OF PROJECT FACILITIES

Two scenarios are presented; one with a state and federal grant (a) and one with no grant (b). A summary of the estimated costs of project facilities is presented in Tables VII.2a and VII.2.b. Details of the respective cost estimates are included in Table VII.4.

Table VII.1 - Estimated Direct Cost of Project Facilities

Proposed Facility	Total Estimated Cost
Principal Spillway	$ 745,700
Auxiliary Spillway	231,700
Dam Enlargement	1,127,200
Access Roads	121,800
Environmental Mitigation	75,000
	$2,301,400

BUREAU OF RECLAMATION (LENDOR) COST

If the loan is obtained through the Small Reclamation Projects Act, the USBR will incur certain costs during the design and construction of the project, which the DNRC and MCWUA must

pay. These costs cover the expenses involved in reviewing and processing the loan application, review of the design, and other costs pertinent to the administration of the loan. The overall costs have been estimated by the Bureau to be $60,000.

INTEREST DURING CONSTRUCTION

A portion of the water delivered by the project (estimated to be about 40%) is to be used for municipal and industrial purposes. Therefore, municipal users will be required to repay interest incurred during construction, compounded annually at the rate of 10-7/8%, for that estimated share of federal funds transferred to the M&I account. These costs amount to approximately $120,000 in principal over the life of the loan with a grant and $170,000 without a grant.

Table VII.2a - Summary of Estimated Project Costs
With Grant Scenario

Total direct cost		2,301,400
Contingencies (25%)		575,350
Subtotal		2,876,750
Project cost increase (15%)		431,500
Subtotal		3,308,250
Engineering		250,000
Construction Administration		222,750
Subtotal		3,781,000
Interest during construction		120,000
Rights-of-Way		-0-
Water rights		10,000
Lender participation		60,000
Processing of application (15,000)		
Administration of Loan (45,000)		
Surveys performed (0)		
Other Costs		
TOTAL CONSTRUCTION COST		3,971,000
Loan application report		300,000
TOTAL PROJECT COST		4,271,000
Less applicant's contribution		
Rights-of-Way	(0)	
Water rights	(10,000)	
Loan application report	(300,000)	
Filing Fee	(1,000)	
State Sponsored Grant	(496,000)	
P.L.984 LOAN AND GRANT		3,464,000
Loan obligation	$2,994,000	
Grant	$ 470,000 1/	
Less Lendor expenditures prior to loan		14,000
Less interest during construction		120,000
TOTAL APPROPRIATION REQUIREMENT		$3,330,000
Less Lendor administration of loan		45,000
TOTAL FUNDS TO BE ADVANCED BY LENDER		$3,285,000

1/ Developed in Table IX.1.

Table VII.2b - Summary of Estimated Project Costs
Without Grant Scenario

Total direct cost		2,301,400
Contingencies (25%)		575,350
Subtotal		2,876,750
Project cost increase (15%)		431,500
Subtotal		3,308,250
Engineering		250,000
Construction Administration		222,750
Subtotal		3,781,000
Interest during construction		170,000
Rights-of-Way		-0-
Water rights		10,000
Lender participation		60,000
Processing of application (15,000)		
Administration of Loan (45,000)		
Surveys performed (0)		
Other Costs		
TOTAL CONSTRUCTION COST		4,021,000
Loan application report		300,000
TOTAL PROJECT COST		4,321,000
Less applicant's contribution		
Rights-of-Way	(0)	
Water rights	(10,000)	
Loan application report	(300,000)	
Filing Fee	(1,000)	
State Sponsored Grant	(0)	
P.L.984 LOAN AND GRANT		4,010,000
Loan obligation	$4,010,000	
Grant	$0	
Less Lendor expenditures prior to loan		14,000
Less interest during construction		170,000
TOTAL APPROPRIATION REQUIREMENT		$3,826,000
Less Lendor administration of loan		45,000
TOTAL FUNDS TO BE ADVANCED BY LENDER		$3,781,000

CONSTRUCTION PROGRAM

Preconstruction. - The exact program for construction for a project of this scope depends to a great extent upon the date the money becomes available. It has been assumed that the loan application will be approved, and the contract validation successfully completed by October 1, 1985. This is the date, it has been assumed, that the money will become available.

The design is to be finished, complete with approved plans and specifications, by July 1, 1986.

Construction Period. - The construction of project facilities is estimated to require 2 years. This allows sufficient time considering the 4- to 5-month construction season at this location. The proposed facilities are to be ready to receive water by May 1, 1988.

Expenditure of Funds. - An estimate of the schedule for the expenditure of funds received from the United States is shown in Tables VII.3a and VII.3b.

ANNUAL OM&R (OPERATION, MAINTENANCE, AND REPLACEMENT) COSTS

Annual OM&R costs have been assessed at $0.90/AF for the past 3 years. It is projected that OM&R costs will be $1.00/AF by 1988 (first payment due).

Table VII.3a - Schedule for Expenditure of Funds
With Grant Scenario

Fiscal Year	Function	Federal Loan Funds	Federal Grant Funds	Applicants Contributed Funds
1987	Water Rights	0		$ 10,000
	Engineering	0		250,000
	Construction Contracts	1,230,000	250,000	
	Lendor Costs	20,000		
1988	Engineering	0		223,000
	Construction Contracts	1,585,000	220,000	23,000
	Lendor Costs	25,000		
TOTALS	APPROPRIATION REQUIREMENT	2,860,000	470,000	
	APPLICANT'S CONTRIBUTION			506,000

Table VII.3b - Schedule for Expenditure of Funds
Without Grant Scenario

Fiscal Year	Function	Federal Loan Funds	Contributed Funds
1987	Water Rights		10,000
	Engineering	250,000	0
	Construction Contracts	1,630,000	0
	Lendor Costs	20,000	
1988	Engineering	223,000	0
	Construction Contracts	1,678,000	0
	Lendor Costs	25,000	
TOTALS	APPROPRIATION REQUIREMENT	3,826,000	10,000

Table VII.4

Interest During Construction

With Grant Scenario (a)

Year of Construction	Appropriation[1/]	1/2 Current Year Appropriation	Sum Previous Year Appropriation	Sum Previous Years Interest	Amount for Computing Interest	Interest
1987	1,250,000	625,000	0	0	625,000	67,970
1988	1,610,000	805,000	0	0	2,122,970	230,870
					TOTAL INTEREST DURING CONSTRUCTION	298,840
					PORTION OF IDC REPAYED BY M&I[2/]	120,003
					ROUND TO	120,000

Without Grant Scenario (b)

1987	1,900,000	950,000	0	0	950,000	103,313
1988	1,926,000	963,000	1,900,000	103,313	2,966,313	322,586
					TOTAL INTEREST DURING CONSTRUCTION	425,900
					PORTION OF IDC REPAYED BY M&I[2/]	171,025
					ROUND TO	170,000

1/ Does not include $470,000 federal grant which will be appropriated but does not bear interest.

2/ 163,580 AF used by M&I divided by 407,360 AF available as developed in Tables IX.3 and IX.4 (payout schedules) times total IDC.

Table VII.5
Estimate of Construction Costs

PRINCIPAL SPILLWAY

Item	Quantity	Unit	Unit Cost	Total
Concrete Demolition	265	CY	$150.00	$ 39,750.00
Upper Spillway Concrete	515	CY	475.00	244,625.00
Baffled Apron Concrete	500	CY	500.00	250,000.00
Slab Anchors	500	LF	50.00	25,000.00
Excavation, Unclassified	15,000	CY	2.50	37,500.00
Compacted Backfill	3,000	CY	10.00	30,000.00
Embankment (Channel and Dike)	10,500	CY	1.00	10,500.00
Gravel Drain (Filters, Bedding)	350	CY	12.00	4,200.00
Riprap (12")	510	CY	10.00	5,100.00
Riprap (27")	160	CY	14.00	2,240.00
Reinforcing Steel	94,000	LB	0.60	56,400.00
Underdrains	600	LF	10.00	6,000.00
Bridge Superstructure	1,050	SF	28.00	29,400.00
Clearing and Grubbing	2	Acres	1,000.00	2,000.00
Dewatering	Lump Sum			3,000.00
		PRINCIPAL SPILLWAY TOTAL		$745,715.00

AUXILIARY SPILLWAY

Item	Quantity	Unit	Unit Cost	Total
Excavation, Unclassified	85,000	CY	1.75	148,750.00
Excavation (Gravel, Borrow, Left Abutment)	15,000	CY	1.75	26,250.00
Embankment (Fill for Gravel Borrow)	15,000	CY	1.00	15,000.00
Embankment (Dike)	4,600	CY	1.00	4,600.00
Riprap (22")	1,030	CY	14.00	14,420.00
Riprap Filter Bed	220	CY	12.00	2,640.00
Road Reclamation	2,000	CY	1.00	2,000.00
Clearing and Grubbing	15	Acres	1,000.00	15,000.00
Topsoil Salvage and Placement	2,000	CY	1.50	3,000.00
		AUXILIARY SPILLWAY TOTAL		$231,660.00

Table VII.5 (continued)
Estimate of Construction Costs

ACCESS ROADS

Item	Quantity	Unit	Unit Cost	Total
Construction Detour				
Earthwork	1,200	CY	$ 3.00	$ 3,600.00
Gravel Surfacing	520	CY	10.00	5,200.00
Temp. Guard Rail	1,000	LF	7.50	7,500.00
Chainlink Fence	1,000	LF	8.50	8,500.00
Traffic Control	3,000	Hrs	17.50	52,500.00
Salvage & Reclamation		LS		11,100.00
		SUBTOTAL		$88,400.00
Auxiliary Spillway Road				
Gravel Surfacing	1,200	CY	10.00	$12,000.00
Cross Drainage	50	LF	30.00	1,500.00
		SUBTOTAL		$13,500.00
Edsall Cabin Access				
Excavation	515	CY	1.75	$ 900.00
Embankment	2,500	CY	1.00	2,500.00
Riprap	200	CY	14.00	2,800.00
Filter Gravel	50	CY	12.00	600.00
Road Surface Gravel	650	CY	10.00	6,500.00
Move Timber Bridge		LS		5,000.00
Cross Drainage	20	LF	30.00	600.00
Clearing and Grubbing	1	Acre	1,000.00	1,000.00
		SUBTOTAL		$19,900.00
		ACCESS ROADS TOTAL		$121,800.00

Table VII.5 (continued)

Estimate of Construction Costs

DAM ENLARGEMENT

Item	Quantity	Unit	Unit Cost	Total
Outlet Tower Catwalk Removal	Lump Sum	---	---	$ 1,000.00
Clearing and Grubbing	40	Acres	$1,000.00	40,000.00
Stripping	9,600	CY	1.50	14,400.00
Excavation	5,500	CY	1.80	9,900.00
Trench Excavation	1,500	CY	5.00	7,500.00
Gravel Drain Fill	2,000	CY	12.00	24,000.00
Reinforced Earth Panels	30,380	Ft^2	22.00	668,360.00
Reinforced Earth Gravel Backfill	12,800	CY	6.00	76,800.00
Reinforced Earth Splash Cap	980	Ft	10.00	9,800.00
Embankment Fill, Core Material	4,250	CY	4.00	17,000.00
Embankment Fill, Gravel Shell	25,250	CY	1.00	25,250.00
Road Fill, Gravel	3,350	CY	6.00	20,100.00
Loose Rock Riprap	1,450	CY	14.00	20,300.00
Impervious Membrane	15,840	Ft^2	0.56	8,870.00
12" Diameter Drain Pipe	1,580	Ft	14.00	22,120.00
8" Diameter Drain Pipe	1,500	Ft	10.00	15,000.00
Guard Rail	1,960	Ft	22.50	44,100.00
Concrete, Sidewalk	73	CY	150.00	10,950.00
Concrete, Foundations	152	CY	350.00	53,200.00
Concrete, Manhole, 5 Ft Sections	11	Sections	500.00	5,500.00
Reinforcing Steel	21,800	Lbs.	0.60	13,080.00
Outlet Tower Catwalk Replacement	Lump Sum	---	---	10,000.00
Monitoring Instrumentation	Lump Sum	---	---	10,000.00
			DAM ENLARGEMENT TOTAL	$1,127,230.00

Table VII.5 (continued)
Estimate of Construction Costs

ACCESS ROADS

Item	Quantity	Unit	Unit Cost	Total
Environmental Mitigation				
Restore Blackmore Campground Fac.	10	Sites	5,000.00	$50,000.00
Parking Area and Boat Ramp	1	LS	10,000.00	10,000.00
Reclamation and Shrub Planting	10	Acres	1,500.00	15,000.00
		ENVIRONMENTAL MITIGATION TOTAL		$75,000.00

CHAPTER VIII
PROJECT EVALUATION

INTRODUCTION

A primary purpose of this chapter is to present an estimate of the Middle Creek Water Users Association's "ability or willingness to pay", which develops a foundation for the financial program. Loan repayment will be derived by annual assessments paid by two types of users; agricultural and municipal (M&I). A secondary purpose of this chapter is to present an estimate of the public benefits of this "multi-purpose" project. Public benefits are presented for flood control, agriculture and recreational values. Another public benefit of this project is a safe dam. An estimate of the monetary loss due to a natural breach of the existing Middle Creek Dam is presented as further justification for cost sharing by the public. However, no annual benefits are included in the project evaluation for this preventive measure. Those that benefit directly from use of the water will share in the loan repayment as according to their "willingness to pay". State or federal grants may be provided for the balance of costs as described in the Cost Estimate chapter.

AGRICULTURAL PAYMENT CAPACITY

Assumptions and Procedures

Repayment of loan funds allocated to irrigation for the project under the Small Reclamation Projects Act is dependent on the ability of the irrigators to repay their obligation each year. To determine the irrigator's "ability to pay", a representative farm was determined for the land area irrigated by water provided from Hyalite Reservoir. The representative farm was

determined by informal surveys with members of the Middle Creek Water Users Association, and consultation with Cooperative Extension Service, Soil Conservation Service, Agricultural Stabilization and Conservation Service and local government personnel.

The representative farm is comprised of 400 acres. The crop mix includes 150 acres of alfalfa-grass hay and 90 acres of barley which are irrigated. Also included are 60 acres of winter wheat (Gaines), 60 acres of subirrigated pasture, 30 acres of summer fallow and 10 acres for the home site and other waste land, not all of which are irrigated. The farm includes a livestock herd of 50 cows. The basic enterprise cost data were taken from two Cooperative Extension documents, "Enterprise Costs for Irrigated Crops in Gallatin County" and "Enterprise Costs for a 200 Cow-Calf Ranch in Madison County". Modifications to these data were made to better represent the size and type of operation in the Middle Creek drainage.

The basic data on commodity yields and prices was supplied by the Montana Crop and Livestock Reporting Services and the Bureau of Reclamation. All yields are three-year simple average yields for Gallatin County. All prices are twenty-year normalized prices as furnished by the Bureau of Reclamation.

The methodology follows procedures adopted by the Bureau of Reclamation and culminates in a financial summary of the representative farm. For additional details in the calculation of agricultural payment capacity for the Middle Creek Water Users Association members, please refer to Appendix B, Farm Budget Analysis worksheets. The most important changes from the Cooperative Extension Service's Enterprise Cost Studies are the separation of interest on investment into debt and equity

portions, and the use of sinking fund depreciation. Given the assumptions used in this study, no payment capacity exists but "willingness to pay" can be made available from the return to equity or return to operator's labor.

Most farm budgets are very sensitive to land prices and returns to operator and family labor, management and equity. In this study, land is valued at $525 per acre, a three-year average price for dry cropland in Crop Reporting District #7 (which includes Gallatin, Madison, Beaverhead, Silver Bow and Jefferson counties). The land price information was from unpublished data collected from the Economic Research Service of the USDA.

The returns to operator and family labor and management were estimated by using employment, hours, and earnings data published by the Montana Department of Labor and Industry. Average annual gross earnings of $14,624 was used as a proxy for the return to operator and family labor and management. This amount must cover the family living, income and social security taxes, and principal portions of any land debt retirement.

Returns to equity were based on 12-year average statistics reported in Economic Indicators of the Farm Sector, Income and Balance Sheet Statistics 1982, U.S.D.A. The average rate of return was 3.8% over this period; a return which farmers have come to accept.

Conclusions

As developed in Table VIII.1, no "Payment Capacity" exists for irrigated agriculture in the Middle Creek service area. However, a "Willingness to Pay" can be made available by

Table VIII.1
Payment Capacity
Middle Creek Water Users Association, Gallatin County, Montana
400 Acre Farm, 390 Acres Farmed

Crop	Acres or Head (A. or Hd.)	Cropping Pattern (%)	Yield or Weight	Units	Unit Price ($)	Total Product (Units)	Farm Use (Units)	Quantity Sold (Units)	Value ($)
Crops:									
Alfalfa-Grass Hay	150	39	3.30	Ton	$67.50	499.50	124.00	375.50	$25,346.00
Gaines Winter Wheat	60	15	66.30	Bu.	4.42	3,979.80		3,979.80	17,591.00
Barley	90	23	69.30	Bu.	2.70	6,239.70	76.00	6,163.70	16,642.00
Pasture, Subirrigated	60	15	5.00	AUM	11.39	300.00	300.00	---	---
Summer Fallow	30	8	---	---					
Aftermath Grazing	(300)		.30	AUM	11.39	90.00	46.00	44.00	501.00
TOTAL CROP SALES									$60,080.00
Livestock:									
Cows	50[1/]			Cwt.	48.30	50.00[2/]		50.00	2,415.00
Replacement Heifers	7			Cwt.	71.43	7.50		7.50	536.00
Bulls	2			Cwt.	60.60	9.00		9.00	545.00
Steer Calves				Cwt.	87.90	120.75		120.75	10,614.00
Heifer Calves				Cwt.	77.50	80.00		80.00	6,200.00
TOTAL LIVESTOCK SALES									$20,310.00

Farm Perquisites[3/]	$6,116.00
Gross Farm Income	86,506.00
Farm Expenses[4/]	-48,501.00
Interest on Indebtedness[5/]	-15,722.00
Livestock (1,512)	
Machinery (11,213)	
Real Estate (2,997)	
Net Farm Income	22,283.00
Allowable Returns to Ownernship	-27,571.00
Operator Labor (8,410)[6/]	
Family Labor (1,037)[7/]	
Management (2,228)[8/]	
Return to Equity (15,896)[9/]	
Payment Capacity	No Capacity Available

1/ Beginning herd inventory.
2/ Total weight of each class of livestock sold. Number of head times weights per head.
3/ Appendix B, last page.
4/ Page 1, Financial Summary Appendix B.
5/ WS I.1-4, Appendix B.
6/ $5/hr. X 1682 hrs, WS 0.1, Appendix B.
7/ $3.64/hr x 285 hr, WS 0.1, Appendix B.
8/ 10% of net farm income.
9/ WS I.1-4, Appendix B.

reducing returns to equity and by reducing operator and family labor and management returns to those of local wage earnings (net farm income of $16,167 minus local wage earnings of $14,624 equals $1,543 per 400-acre farm). Either alternative reduces the already minimal returns to agricultural enterprises. For purposes of this study, a $5/ AF assessment is recommended as a fair and equitable sharing of rehabilitation costs by agriculture. Anything less will likely be protested by municipal users. A willingness to pay this amount has been demonstrated by the MCWUA Board of Directors at their 1984 annual meeting. The $5/AF is simply a negotiated value.

There exists approximately 25,000 acres of irrigated land that are served by direct flow rights within the Middle Creek drainage. Within this area, approximately 60% are farms which have contracts for Middle Creek storage water or 14,750 acres. It is estimated that 60% of this area or 8,950 acres are irrigated as per the crop mix described earlier. Not all of these lands are irrigated in any one year and it is estimated that 5,000 acres have historically received storage water in a dry year or 1/AF. Given a 7,184 AF first year contracted capacity (10,184 AF active capacity less 3,000 AF M&I) and a charge of $5/AF, $35,920 would be generated. Assuming a $1.00 operation and maintenance and reserve fund charge, $4/AF would be available for repayment. It is assumed that the agricultural service area would reduce to approximately 10,250 acres at the end of 40 years and 5,005 AF would be delivered to agriculture with 5,179 AF delivered to M&I service.

MUNICIPAL PAYMENT CAPACITY

Needs and Usage

The City of Bozeman has presently contracted for approximately 2,805 AF of water from Middle Creek Reservoir and has expressed a desire for additional water. The new increment of storage is

allocated to M&I use for Bozeman and this use repays the remaining obligations of the project. These costs are compared to alternative costs of providing this increment of water. Two alternatives were examined: 1) developing high yield municipal wells, and 2) purchase and transfer of existing storage rights from agricultural to municipal use. Basic engineering and cost estimates for these two alternates are developed in the following paragraphs.

M&I Use. The first step in assessing reasonable value for M&I water is to determine the projected needs of the City of Bozeman, the largest M&I user. The present service area of Bozeman is estimated to cover 9 square miles and served a 1980 population of 21,650. Population projections were made to the year 2020 which is near the end of the 40-year loan repayment period. An Area Wide Water Plan was prepared in 1973 by Thomas, Dean & Hoskins, Inc. (TDH) for the City of Bozeman. A population of 36,000 by year 2000 was approved for this plan. A service area of 24.3 square miles was included in the 201 Facility Plan. It is assumed that this area would not expand but become denser by year 2020. Most smaller western cities do not exceed a density of 2000 people per square mile. This assumption would set a maximum population limit of 48,600 within this area. However, the following paragraphs develop a more exact projection of population.

Between 1970 and 1980, the population of Bozeman grew from 18,670 to 21,645, an increase of 15.9% Over this same period, the number of housing units rose from 5,736 to 7,971, an increase of 39.0%. For comparison, the population growth for Gallatin County, the State of Montana, and the United States was 31.9, 13.3, and 11.0%, respectively, between 1970 and 1980.

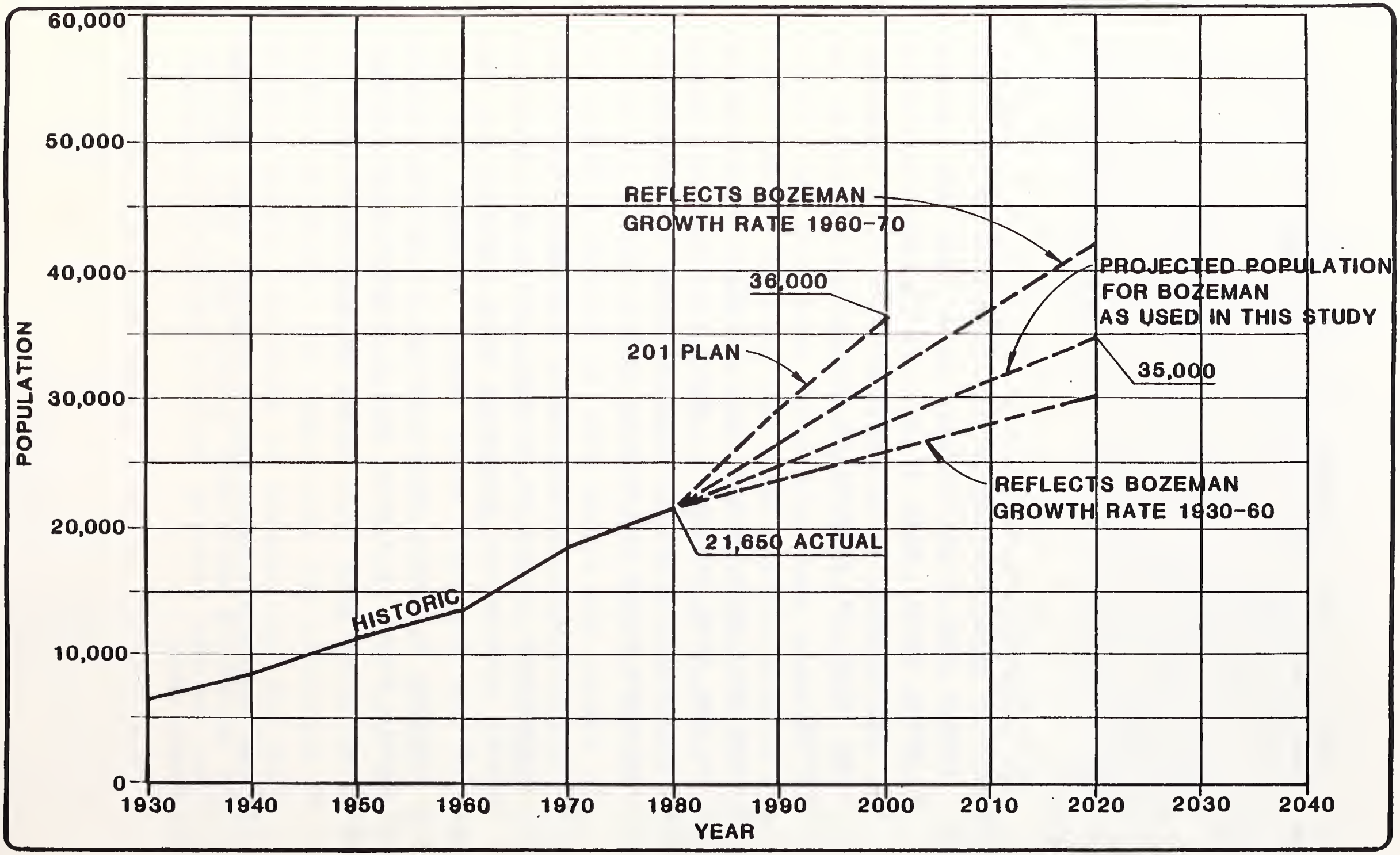
During the past decade, Gallatin County was one of the principal growth areas within Montana. This growth resulted from three primary causes: 1) an expansion of the university enrollment, 2) increases in tourism and travel-related jobs, and 3) growth in durable manufacturing employment. As a result, Gallatin County grew much faster than the state, with much of the growth (over half) resulting from new people moving into the area as opposed to natural population growth (births less deaths).

As was the case in many areas of Montana, the city of Bozeman's population growth was significantly less than the county growth. In other words, most of the growth was found just outside of established city boundaries. City growth, therefore, was often as related to annexation policy as to economic activity.

The future local population growth rate is likely to be slow in comparison to the last decade[1/]. There is, however, every indication that Gallatin County will continue to experience population increases beyond the natural growth level.

Aside from the population trends shown in Figure VIII.1, no "official" projections (state or federal) exist for Bozeman. However, several alternative forecasts were explored in the development of the long-term water demand forecast for the city. For example, a simple extrapolation of the historical population levels found in Figure VIII.1 suggest that if the historical growth trend were to continue the population of

1/Many Montana economists/demographers expect that tourism expansion and university enrollment growth rates will decline in the future, thereby reducing Gallatin County's historical population growth rate.



MIDDLE CREEK DAM REHABILITATION

POPULATION TREND BOZEMAN, MONTANA

8M087.113

SEPTEMBER 1984

FIGURE VIII.1

HKM ASSOCIATES
ENGINEERS·PLANNERS

Bozeman would increase to approximately 27,500 by the year 2000. This level (27,500) would represent approximately 12,500 households versus the reported 1980 census household level of 7,512 for the city proper - a 66% increase. By the year 2020 (near the end of this study's planning horizon), the simple trend suggests a population and household level of approximately 35,000, and 15,000, respectively. For comparison, the MASS/II projection series, developed for the Montana Department of Commerce/U.S. Environmental Protection Agency, suggest Bozeman population levels of between 23,500 and 32,500 by the year 2000.[1/]

The MASS projections rely on several important assumptions. First, the population proportion of Bozeman relative to the county total remains constant at the 1980 level. Second, the trend series (32,500) assumes that the 1967-79 increase in basic employment by sector would continue into the future. The second assumption may not be valid. Third, the low series (23,500) assumes only a natural growth increase (i.e., no further immigration into the area). The high and low series probably are the extremes of the likely range of population levels.

The MASS projections call for an increase in the number of households from 7,512 in 1980 to 14,900 in 2000 for the high series and 10,700 for the low series. The high Bozeman household series represents an increase of 98% while the low series represents an increase of 42% over the next 16 years. For comparison, the more recent Census Bureau projections suggest a national increase in household formation (from 1980 to 2000) of 40% versus the MASS/II range of between 42 and 98%. The national projections and low MASS/II projections are similar due to common assumptions of zero net migration and birth and death rates.

1/Montana Alternative Simulation System (MASS/II), ECO Northwest, Ltd., 1982. This projection series begins in 1980 and ends at the year 2000.

If the national census projections (P-25 No. 805/No. 952) are indicative of growth under zero migration conditions, then Bozeman could expect, at the minimum, an increase of approximately 54% in households by the year 2020. Since the MASS projection ends in the year 2000, the simple trend approach represents the only alternative technique for the 2020 projection. As mentioned earlier, the 2020 trend projection calls for a population level of 35,000 and for approximately 15,000 households, which represent increases of 62 and 100%, respectively, from the 1980 census level. The annualized growth rates (compounding) are 1.2% for population and 1.8% for households over the forty-year period 1980-2020. Both growth rates are somewhat lower than the 1970-80 experience when the annual city population and household growth rates averaged 1.5 and 3.4% per year, respectively.

The lower population growth of 1.2% is reflective of an expected statewide slowdown in basic employment growth relative to the 1970s, when growth was unusually strong. The lower rate, nevertheless, still implies continued immigration. The lower household formation rate of 1.8 also reflects a slowdown in comparison to the 1970s, resulting from fewer individuals in the 20- to 30-year-old age bracket (i.e., the end of the "baby boom" phenomenon). In other words, with fewer young people to develop families, household growth rates will be less. Considering the previous discussion, a population of 35,000 is assumed for Bozeman for year 2020. This number will provide a basis for water demands discussed in the following paragraphs.

The next consideration is the projected average yearly usage as compared to available supply. Diversions typically range from 175 GPCD to 450 GPCD for most Montana cities.

Present diversions by the City of Bozeman are 310 gallons per capita per day (GPCD) as reported in City of Bozeman, Municipal Water Inventory, Page 8. Consumption rates are also estimated at 236 GPCD in this report. Diversions are significantly higher than consumption for several reasons including the following:

- Diversions have been constant but hourly and daily demands of the city are variable, necessitating overflow from regulating reservoirs.

- Cold weather does not allow manipulation of the diversion gates on Bozeman and Hyalite creeks. The gates are set in late fall so that adequate water can be provided throughout the winter, resulting in overflow.

- Water mains are old and pressures are very high in parts of the city. This results in considerable leakage losses.

- Releases from storage in Hyalite Reservoir must be relatively constant.

Consumptive use is high for the following reasons:

- Bozeman delivers water to Montana State University; students may or may not be included in the population numbers.

- Bozeman supports laundries, motels, restaurants and other tourism-related industries which service Yellowstone National Park and other areas. These activities will increase water requirements on a per capita basis.

. Although a metering program is underway, not all residential services are metered.

It is assumed for purposes of this report that the City of Bozeman would continue to improve its system and diversion requirements will decrease. Given the tremendous cost of these improvements and an existing heavy debt load, diversions are not expected to reach city goals by the end of the 40-year projection period. With this in mind, a diversion requirement reduction of 20% or 245 GPCD has been assumed for this study. As developed in the next paragraph, this level of diversion will utilize the storage available in Hyalite Reservoir. It is assumed that purchase of this water will be more economical than the massive expenditures necessary to reduce diversion rates below 245 GPCD.

Given a population of 35,000, the diversion requirement equals 3,130 MGY or 9,606/AF/yr. The diversion requirement must be increased by 1,035 AF (20% x 5,179 AF storage)[1/] for instream water loss from Hyalite Reservoir to the diversion headworks for a total supply requirement of 10,641 AF. It has been estimated by the city that Lyman Creek will supply 1,453 AF of average yearly needs, Bozeman Creek - 4,009 AF/yr and the existing Hyalite Reservoir Storage - 2,805 AF/yr, for a total of 8,267 AF/yr. (See City of Bozeman, Municipal Water Inventory, September, 1983.) A projected need of 10,641 AF would indicate a deficit of 2,374 AF/yr by year 2020. The city could meet demand for water with the existing supply until year 2020 only if the occurrence of projected growth (35,000 population) and minimum diversions (200 GPCD) became an

1/ The 20% reduction has been used historically in delivering water from Hyalite Reservoir to the city diversion. The 5,179 AF is the storage available to City of Bozeman in year 2027 with the proposed 2,334 AF increase in storage plus 40 AF of existing storage not contracted (See Tables IX.4 and IX.5).

eventuality. Growth and usage are very difficult factors to control. The city would still experience unacceptable short-term shortages during low flow winter periods and hot, dry summer periods without additional storage. Existing operational constraints, requiring summer time diversions similar to irrigation diversions, are also a factor in utilizing the available water supply.

In summary, it can be concluded that the City of Bozeman must secure additional water to meet its future needs. Nearly all of the deficit can be met by Hyalite Reservoir storage. This fact was considered in the decision of a maximum 10-feet increase in water surface elevation. Additional supplies, if needed, will have to be met by additional purchases of agricultural water, development of wells and improvements to the distribution system.

Ground Water Alternate

The next step of this analysis is to consider alternative sources of water and their costs. This analysis will determine an upper limit for M&I allocations of repayment.

The purpose of this section is to present background information concerning a ground water system to provide an alternate source to satisfy the projected Bozeman water supply deficit for the year 2020. The projected deficit is 2,500 to 4,000 AF/yr (depending upon improvements to the system) on an annual basis and 6 million gallons per day on a peak daily basis.

One of the most important factors concerning the development of ground water as a water supply source, is the geographic location of the source with respect to the point of use. If a

source can be found at or near the point of use, then a significant cost advantage might be achieved by a reduced length of delivery line.

Therefore, an evaluation was made of the capability of ground water within and immediately adjacent to Bozeman to sustain the peak daily and average annual demand of the city. Several sources of information were used for the evaluation and included reports published by the U.S. Geological Survey and the Bureau of Reclamation (Hackett and others, 1960; USBR, 1958). Additional sources included published and unpublished reports related to the occurrence of ground water in Bozeman by personnel associated with the Department of Earth Sciences, Montana State University, Bozeman, Montana (Brown and others, 1983). Additional data was obtained from well logs on file with the Montana Bureau of Mines and Geology (MBMG) in Butte, Montana and interviews of MSU Department of Earth Sciences personnel (Custer, 1983), MBMG personnel (Miller, 1983) and a Bozeman area water well driller (Jones, 1983).

DISCUSSION

At the request of the Bureau of Reclamation, the U.S. Geological Survey (USGS) performed an evaluation of the total water resources of the Gallatin Valley. The study was performed between 1953 and 1957 and was published in 1960 as Water Supply Paper 1482, Geology and Ground Water Resources of the Gallatin Valley, Gallatin County Montana (Hackett and others, 1960). The study was performed to assist the Bureau of Reclamation in irrigation planning for the Three Forks Division of the Missouri River Basin Project. (Bureau of Reclamation, 1958)

The USGS study indicated that large quantities of ground water supplies are available in parts of the Gallatin Valley. The study pointed out that the total ground water discharge varies between 120,000 and 320,000 AF/yr and averaged 240,000 AF/yr for the period 1934-1953. The USGS indicated that average specific yield for the Gallatin Valley as a whole, averaged 0.15. The available ground water and specific yield were found to vary from area to area throughout the valley. (Bureau of Reclamation, 1958)

Gallatin River Alluvium, Gateway and Belgrade Areas

Only the alluvial deposits on the floor of the Gallatin Valley were found by the USGS to contain ground water in sufficient quantities to support irrigation by pumping from wells. Transmissivity of the alluvium in the Gateway and Belgrade areas of the Gallatin Valley ranged from 6,680 to 89,570 ft^2/day. (Bureau of Reclamation, 1958)

Based on the USGS study, the Bureau of Reclamation estimated that a total of 193 irrigation wells completed in the alluvium in the Gallatin Gateway and Belgrade areas of the Gallatin Valley could produce 92,290 AF of water per year. The Bureau of Reclamation proposed to pump the water in July, August and September of each year from the wells for irrigation purposes. (Bureau of Reclamation, 1958)

A complete evaluation of the suitability of ground water in the alluvium for drinking water could not be made as all parameters of the Primary Drinking Water Standards were not included in parameters tested by the USGS for the 1960 report. Water from the alluvium was relatively low in dissolved solids and generally a calcium bicarbonate type. The concentration of dissolved solids ranged from 154 to 398 mg/l. (Hackett and others, 1960)

Bozeman Fan and East Fork Gallatin River Alluvium, Bozeman and Vicinity

Bozeman is located on the Bozeman alluvial fan and the flood plain of the East Gallatin River. The Bozeman alluvial fan, which is composed of material derived from the Gallatin Range, slopes northward from the mouth of Hyalite Canyon where Middle Creek enters the Gallatin Valley. The fan is bounded on the southwest by Goochs Ridge and on the southeast by Bozeman Creek. It merges with the floor of the Gallatin Valley on its northwest margin and with the floodplain of the East Gallatin River on its northeast margin. Area of the fan is about 56 square miles. (Hackett and others, 1960)

The transmissivity of the alluvial fan deposits, determined by the USGS at six locations, ranged from 3,480 to 8,690 ft^2/day and averaged about 6,420 ft^2/day. The USGS indicated in 1960 that no more than 500 gpm should be expected from wells completed in these deposits. (Hackett and Others, 1960)

Calcium and bicarbonate were the major constituents of water from the Bozeman fan in samples obtained by the USGS for the 1960 report. Dissolved solids concentrations ranged from 157 to 343 mg/l and were independent of depth. A complete evaluation of the suitability of water from the Bozeman fan for drinking water purposes could not be made due to the lack of data.

The USGS was unable to determine the transmissivity of the alluvium of the East Gallatin River. Existing data at the time of the USGS study indicated that the alluvium of the East Gallatin River would not yield large quantities of water to wells. (Hackett and others, 1960)

Several sources were investigated to determine if additional information has become available since 1960 concerning the occurrence and development potential of ground water in or immediately adjacent to Bozeman. The results of a study published by personnel associated with MSU Department of Earth Sciences indicated the presence of a buried valley on the University campus adjacent to Bozeman (Brown and others, 1983). The feasibility of developing these deposits has not been determined and is dependent on additional studies to determine if large quantities of ground water withdrawal can be supported. (Brown and others, 1983; Custer, 1983)

Approximately 50 well log reports on file with MBMG were reviewed of wells drilled and completed within Bozeman. Purpose of the review was to determine if any ground water development since the 1960 USGS study has revealed the presence of deposits within the city that could support wells of high sustained yield (1,000-1,500 gpm). Most of the logs reviewed were for wells drilled since 1959. Thickness of clay, silt, sand and gravel deposits within the city in the wells drilled since 1959, ranged from 6 to 190 feet and yields ranged from 15 to 500 gpm.

CONCLUSIONS

There is no evidence at the present time that an aquifer exists in or immediately adjacent to Bozeman that could support the projected deficit of 2,500 to 4,000 AF/yr or a peak daily demand of 6 million gallons. Based on available data, it appears the alluvial deposits near Gallatin Gateway, approximately 10 miles southwest of Bozeman, are the most favorable for development of ground water as a source to satisfy the City of Bozeman's projected water deficit in the year 2020.

ALTERNATIVE COSTS FOR GROUND WATER DEVELOPMENT

A site was selected near Gallatin Gateway for six 1000 gpm capacity wells for the ground water alternative (See Service Area Map, Figure III.1, Chapter III). Available USGS and Bureau of Reclamation information indicate that the alluvium in this area could reasonably be expected to support the six production wells. However, a testing program involving drilling and test pumping would be required before a final decision is made to proceed with ground water development in the Gateway area.

Six wells, each producing 1,000 gpm per well and operating 12 hours per day, would be capable of producing 4.32 MGD on an average daily basis and have a peaking capacity ranging between 6.5 MGD (pumping 18 hours per day) and 8.64 MGD (pumping 24 hours per day). The proposed location of the wells and the close interrelationship between ground water and surface water in the Gallatin Valley, could result in from 20 to 90% of the water produced by the wells being induced infiltration from the Gallatin River. The actual amount supplied directly by induced infiltration would depend on the season and location, demand and duration of pumping from the wells.

It was assumed in this alternative that water produced by the wells would be of relatively high quality and would require only disinfection by chlorination as treatment. It was estimated that about 11 miles of 24-inch-diameter transmission line would be required to move the water from the well field to the Bozeman water treatment plant and terminal reservoir.

The capital costs for the well field and transmission line are summarized in Table VIII.2. The annual costs are shown in Table VIII-3.

In summary, it is estimated that a well field will result in costs ranging from $65 to $105/AF for water. Costs for transporting the water from a well field near the West Gallatin River to the Bozeman Treatment Plant would add $160 to $260 to the annual costs. Costs could exceed $250/AF for a workable, large scale development of ground water.

Purchase of Storage Rights

The City of Bozeman has the option of purchasing direct flow or storage rights from existing users within the Hyalite Creek drainage area. Use of direct flow rights will be limited to the volume of water historically depleted and to a time of use that is consistent with the location and historical use of this water. Thus, purchase of a right that is used for irrigation will yield approximately 1 AF/acre of land from which the water is severed. This value is based on an average net irrigation requirement determined to be 1 AF/acre from calculations by the SCS TR-21 Blaney-Criddle technique (see Chapter IV, Water). It is estimated that the conveyance and on-farm efficiency ranges from 25% to 40% in this basin. This would indicate a diversion of 4 to 2.5 AF/acre, much of which returns to the stream for diversion by other appropriators. For this reason a use different from irrigation should be limited to the actual depletion associated with the irrigation, not the amount historically diverted.

Table VIII.2
Summary of Ground Water Capital Costs

	Item	Unit	Quantity	Unit Cost	Extended Cost
1.	Wells	Each	6	$30,000	$180,000
2.	Pumps, Motors and Electrical	HP	840	300	252,000
3.	Valves/Piping	Each	6	20,000	120,000

Table VIII.2 (continued)
Summary of Ground Water Capital Costs

	Item	Unit	Quantity	Unit Cost	Extended Cost
4.	Well Houses/ Sitework	Each	6	27,000	162,000
5.	Chlorination Equipment	Each	6	7,000	42,000
6.	Telemetry System	L.S.	1	75,000	75,000
		Subtotal			$831,000
	Contingency (20%)				166,200
		Subtotal			$997,200
	Engineering, Legal, Const. Adm. (15%)				149,580
		Total, Well Field			$1,146,780
		Budget			$1,150,000
	Transmission Pipeline				
1.	24" Dia. Pipe	L.F.	56,700	$75.00	$4,252,500
2.	Highway Crossing	Each	2	25,000	50,000
3.	Misc. Valves and Fittings	L.S.	1	50,000	50,000
		Subtotal			$4,352,500
	Contingency (10%)				435,250
		Subtotal			$4,787,750
	Engineering, Legal, Const. Adm. (12%)				574,250
		Total, Transmission Line			$5,362,000

Table VIII.3
Summary of Ground Water Annual Costs

Well Field

Repayment (10-7/8%, 20 years)	$1,150,000 x .1245	$143,175
Energy Costs $\frac{840\ HP}{.90\ EFF}$ x .746 $\frac{KW}{HP}$ x 3500 Hrs. x $.035/KWH		85,000
O&M Costs	$1,150,000 x .03	34,500
	TOTAL	$262,675

Cost per AF (2,500 AF) = $105.07
(3,000 AF) = $ 87.56
(4,000 AF) = $ 65.67

Transmission Pipeline

Repayment (10-7/8%, 40 years)	$5,362,000 x .1105	$592,500
O&M 5,362,000 x .01		53,620
	TOTAL	$646,120

Cost per AF (2,500 AF) = $258.45
(3,000 AF) = $215.37
(4,000 AF) = $161.53

Total Cost per AF = $225 to $365

There is also an assumed loss associated with transmission of storage water from the reservoir to the city's point of diversion. This loss has been historically set at approximately 20%. Thus the yield of each acre-foot of water released from storage is 0.8 AF at the city's diversion point.

Prior sales usually establish a market value for rights which are "severed and sold." Sales have been limited in the Bozeman area historically and information is limited. The City of

Bozeman has recently implemented a policy whereby developers of subdivisions desiring annexation must procure adequate water rights in the name of city before annexation. This will likely create additional sales activity in the future.

Three rights have been sold or transferred recently which would indicate a range of values for water rights. The first right was sold by Litchenburg Land and Cattle Company to the City of Bozeman for $61,000. The right consisted of a direct flow of 7.5 cfs with three early priority dates and 50 AF of storage in Hyalite Reservoir. There is presently a question as to whether Litchenburg Land and Cattle Company actually held the rights when they were sold. As a part of the approval process with the Water Rights Bureau, DNRC, an agreement was reached as to 300 AF of consumption on 250 acres of land on which the water was applied. A value for nonbeneficial consumptive use was developed and allowed for diversion in the above agreement. This additional consumptive use is a result of several factors including use by trees, willows and other phreatophytes which consume water as a result of the irrigation practices. Evaporation loss in canals is another factor. Deep percolation of water to the ground water system which does not return in time to benefit users downstream is another factor. This consultant does not believe that these uses will cease as a result of severing irrigation water from a small portion of land within the larger system. For example, established trees and willows will still consume water derived from surrounding irrigated fields, canal losses, etc., as their deep root systems are established. Therefore, nonbeneficial consumptive use was not considered in the yield of an agricultural water right transfer. With the 50 AF of storage included, the total amount allowed for diversion by the city was 350 AF. Considering effective rainfall and long-term, weighted consumptive use of all crops, the depletion by irrigation would be closer to 1 AF/acre with a full supply of water, or 250 AF

(see Chapter IV, Water). Thus the initial cost of the water would be $175/AF if 350 AF were yielded or $244/AF if 250 AF were yielded. Given the latter case and amortizing this cost over 40 years at 10-7/8%, the annual cost would be $27/AF.

The second case is a Hyalite Reservoir storage contract sold at public auction by the Small Business Association. In this case 50 AF sold for $18,500 or $370/AF. Considering a diversion of 40 AF, the annual cost would be $50/AF given the terms above. It is interesting to note that the local reaction to this sale was one of surprise as to the high value.

The third case evolved out of the city's requirement for a firmer water supply before any additional annexation could occur. In this case 100 AF of Hyalite Reservoir storage was obtained and the contract was transferred to the city. Telephone conversations with the developer indicated a sales price of $11,000 or $110/AF. With 80 AF diverted this cost would amortize to $15/AF given the terms above. This price was deemed reasonable by the local agricultural interests who were probably a factor in determining this value.

One measure of the agricultural value of water is the amount by which control of a right increases land values. Based on conversations with officials of the Federal Land Bank it is estimated that a typical value for irrigated land with a good water supply would be $1,200/acre. An average value for dryland is estimated to be $525/acre. Thus, irrigation water and facilities to deliver it may increase land values by $675/acre. Assuming that the yield of the agricultural right would be 1/AF/acre, and one-half of the increased land value attributable to the right , the annualized cost would be $37/AF. This number should be considered only as a measure of the potential value of the water to irrigated agriculture.

In summary, purchase of agricultural water rights are a definite option for the City of Bozeman, given a price of $25 or $35/AF of divertable water. However, resources are limited and purchase prices will increase as the availability of the resource decreases. Also, costs are not included for administrative and legal costs to obtain the rights, react to protests by senior appropriators, etc., which may be expected with this process.

RECREATIONAL VALUES

User Day Values

There are a variety of methods available to estimate recreational values. After reviewing the literature associated with each method, the Federal Resource Planning Act Guidelines were selected as the most appropriate technique to determine the recreational values of the Hyalite Reservoir.

Over the course of several decades, the Forest Service (FS) has developed recreational day values for estimating the benefits of public lands. At the present time, their value estimates represent an approximation of the market value of the recreational attributes associated with a lake, in this case Hyalite Reservoir. The estimates (dollars per 12-hour visitor day) embody only the "market" value of the resource itself. Campground fees which are collected from users are a common proxy of market value, while fishing and hiking fees are not levied; therefore, market values must be estimated. The current day use value for fishing is $11.00 and $5.00 for camping.[1/]

1/ U.S. Department of Agriculture, U.S. Forest Service. 1985 RPA Program Update: Resource Benefit Values.

The market values used by the FS do not embody either actual travel expenditures or full willingness to pay, which includes consumer's surplus. No expenditure estimates are available for Montana; however, the U.S. Fish and Wildlife Service reports that the average national expenditure per fishing day was $11.50 in 1974 dollars.[1/] In addition, the consumer surplus values as estimated by the FS are $6.00 and $3.00 per visitor use day for fishing and camping, respectively. The consumer surplus values represent willingness to pay in excess of actual market price; in other words, the full value of the resource to the consumer.

Recreational Visitor Days

Representatives of the Forest Service (USFS) and Montana Department of Fish, Wildlife and Parks (DFWP) were interviewed concerning their recreational visitor day estimation technique. The USFS maintains the Recreational Information Management (RIM) system that provides estimates of visitor use days per facility by type of use. These values were presented in Table VIII.4. Since the RIM system is subject to considerable estimation error, particularly for small areas or for accurate discrimination between type of use, an attempt was made to verify the USFS data. Ross MacPherson of the Gallatin National Forest reported that during 1983 there were 18,100 estimated visitor days within the Hyalite basin. It was his view that two-thirds of the total visitor days were lake-related recreation, a value consistent with the RIM system data in Table VIII.4. The USFS was also able to provide up-to-date traffic volume and flow patterns within the area.

1/ U.S. Department of the Interior, U.S. Fish and Wildlife Service. 1975 National Survey of Hunting, Fishing and Wildlife - Associated Recreation, Washington, D.C.

These traffic data suggest that there are approximately 23,200 recreational trips per year within the basin. Approximately 13,000 of the trips terminate at the reservoir, generating about 33,000 visitors per year or, assuming a six-hour average stay, 16,500 12-hour visitor days per year.

TABLE VIII.4

Middle Creek Reservoir Study Area Visitor Days

Area	Visitor Days	
Hood Campground		
Boating	1,200	
Camping	2,100	
Picnic	1,000	
		4,300
Langhor Campground		
Camping	1,500	
Picnic	1,000	
		2,500
Palisade Falls		
Picnic	1,000	
Recreation Trail	1,900	
		2,900
Blackmore		
Camping	1,700	
Picnic (estimated)	900	
		2,600
TOTAL		12,300

Source: U.S. Forest Service, Recreational Information Management System.

Total visitor days for the study were estimated to be 13,500 days per year. This figure is an average of the RIM estimate (12,300), Ross MacPherson's estimate (12,100), and the USFS road count estimate (16,500).

The DFWP estimates that there were between 11,000 and 12,000 three-hour fishing days in the entire basin last year.[1/] Of this total, approximately 4,900 fishing days (12-hour days) were thought to be associated with the lake itself. Similarly, an unpublished Master's Thesis by Raymond Zubik, Jr. reports approximately 4,700 (12-hour) fishing days for 1981 and 1982.[2/] This fishing day value was slightly higher (5,700) in a 1975 fishing pressure survey conducted by the DFWP. Again, a value of 5,000 fishing days per year was used in the recreational resource values (Table 2) by averaging the DFWP estimate for 1982-83 (4,900), the DFWP estimate for 1975 (5,700), and Zubik's estimate for 1981-82 (4,700).

Over the long term (40 years), the present value of $97,500 (shown in Table VIII.5) annually discounted at 8-3/8% would be $1,117,529. This value represents the total discounted benefits associated with the reservoir over the financial life of the proposed rehabilitation.

1/ George Holton, Annual Fishing Pressure Survey, Montana Department of Fish, Wildlife and Parks, 1982-83.

2/ Raymond John Zubik, Jr. 1983. The Fishery of Hyalite Reservoir, Montana, With An Evaluation of Cutthroat Trout Reproduction in Its Tributaries. Unpublished Thesis, Montana State University, Bozeman, Montana.

TABLE VIII.5

Hyalite Reservoir Recreation
Use Days (12-Hour)

Recreational Activity	Days	Volume Per Day	Total
Fishing/Boating	5,000	$11.00	$55,000
Camping/Hiking/ Picnics	8,500	5.00	42,500
TOTAL	13,500		$97,500

Sources: Montana Department of Fish, Wildlife and Parks.
U.S. Forest Service, 1985 RPA Program Update: Resource Benefit Values,
U.S. Forest Service, Gallatin National Forest.

AGRICULTURAL VALUES

The present Middle Creek facility provides 5,005 AF of storage and irrigates 5,000 acres of land. Average use per acre would be approximately one AF.

As developed previously, this land could exhibit "willingness to pay" of $5.00/AF of water. "Willingness to pay," however, does not include producer surplus values, that is, the full value of the water to the user. Table VIII.6 provides various estimates of the "total" value of water that the DNRC has used for planning purposes and benefit/cost ratio calculations over the past decade.

The average value (about $35/AF) embodies both the market value of the water (i.e., actual water payment) plus the net increase in income (i.e., the residual marginal value product) associated with irrigation water use per AF. In other words, if a rancher paid $5/AF diversion including OM&R, the producer surplus would be $30/AF assuming water were valued at $35/AF.

TABLE VIII.6
Irrigation Benefit - Value Per Acre-Foot

Source	Value Per Acre-Foot
Snyder (DNRC)	$37
Corrigall (DNRC)	$17.25
Steinbeck (DNRC)	$30-$40
Vinnard (DNRC)	$32
Yellowstone Impact Study (DNRC)	$34
Long (DNRC)	$37
Luft (AMEC Inc.)	$44
Finnie (ECO Northwest, Ltd.)	$34

The Montana values shown in Table VIII.6 are generally similar to the value of water throughout the western United States. Clearly, areas that raise vegetables have higher water values (at least triple); however, the marginal value of western agricultural water (excluding the lower Columbia Basin) averages approximately $35/AF in $1983.[1/]

Assuming 5,005 AF storage, the discounted present value of water (at 8-3/8%) over 40 years at $35/AF would be $2,007,826. Additionally, if the city of Bozeman does not immediately use their full allocation out of the new project (which is probable), then up to 2,300 AF of storage would be available to irrigate up to 2,300 acres of additional land, assuming a diversion of 1 AF/acre.

HKM estimates the study area to be approximately 25,000 acres. According to the Montana Crop and Livestock Reporting Service, approximately 60% of harvested lands in Gallatin County are under irrigation. Applying this factor (60%) to the total Middle Creek area would imply, everything being equal, that up to 15,000 acres could be supplied supplemental water if water were available. The present value of water ($2 million), therefore, may somewhat understate the total value (with new temporary sales) as "normally calculated" by state or federal water planners.

FLOOD BENEFITS

An analysis was completed as to the effects of Hyalite Reservoir upon the 100-year flood plain in the Hyalite Creek valley. Because the reservoir is located high in the drainage,

1/ Frank, Michael D. and Bruce R. Beattie. 1979. The Economic Value of Irrigation Water in the Western United States: An Application of Ridge Regression. Technical Report No. 99, Texas A&M University.

the reduction in floodplain area was minimal. The before-dam 100-year frequency flood was determined to be 740 cfs and the after-dam 100-year flood was 738 cfs. For this reason flood benefits were not considered in the cost-benefit analysis.

A second study was completed given the occurrence of the probable maximum flood (PMF), induced dam breach as detailed in Probable Maximum Flood Damage Estimates, Hyalite Reservoir, ECO Northwest, June 1984. The floodplain boundaries were superimposed on aerial photographs and properties were inventoried by category. In summary, 496 residences, 1 apartment house, 48 farm homesteads, 150 trailers, 34 camp trailers and 15 major bridges lie in this floodplain. Using FIA flood damage vs. depth curves, a damage estimate of $13.8 million was developed. Considering automobiles, commercial property, farm equipment, livestock, human life and public infrastructure, losses have been conservatively estimated to exceed $30 million. This value is based on doubling the calculated losses. This value compares well to those losses experienced during the Teton Dam failure on an AF basis.

Since the PMF is such a remote event, it is difficult to place an economic value upon its occurrence. However, it must be remembered that a flood much less remote than a PMF greater than 5,600 cfs could result in a dam breach. (Reported capacity of existing spillway with the water surface at the dam crest, COE, Phase 1 Inspection report.) Should Middle Creek Dam breach during an unusual flood event, the cost would be significant. No public benefit for dam safety is developed for this study; only an estimate of potential losses as reported above.

COST-BENEFIT ANALYSIS

The total project cost (with grant scenario) of this rehabilitation is $4,273,000 as developed in Chapter VII. Benefits, both direct and indirect, accrue from irrigated agriculture, municipal and industrial water supply and recreational benefits. The discount rate used in this analysis is 8-3/8%.

As developed previously, the present value of agricultural water is $2,007,826 based on 5,005 AF of water marketed. Assuming a least cost alternative of $35/AF for agricultural water purchases and 5,100 AF of water supply, the present value of M&I water would be $2,045,937. Recreational values show a present value of $1,117,529. Total benefits would equal $5,171,292 divided by $4,273,000 of costs; the cost-benefit ratio is 1.2:1.

CHAPTER IX
FINANCIAL PROGRAM

SOURCES OF FUNDING

Several sources of financing were examined and the following financial program is recommended. A primary source of funds for the agricultural allocation will be a loan under the Small Reclamation Projects Act of 1956 (P.L. 84-984) as administered by the Bureau of Reclamation. This source of funding would allow interest free repayment of a loan over a 40-year period for that allocated portion of storage water delivered to lands in commercial agricultural production. These terms would allow farmers to repay a portion of the loan within the limits of their "willingness to pay." This "willingness to pay" has been assumed to be $5/AF from discussions with DNRC and local farmers. This value was determined by negotiations with the MCWUA.

That portion of M&I storage water actually released from the reservoir, as compared to agricultural use, will bear interest. This allocation has been projected in the payout schedules (columns 3 and 4) but will be calculated each year and an appropriate payment made.

Two sources of funds are possible for the municipal and industrial allocations of cost. The first source would be inclusion in a loan under the Small Reclamation Projects Act. Interest will be charged annually on those portions of the loan allocable to M&I service. Calculations are based on the percentage of M&I water delivered, compared to the total amount of water delivered for that year. The interest rate will be set at the time of signing of the repayment contract. The FY-1985 rate is 10-7/8%. This source of funds has the

advantage of a long term of 40 years. The second source of funding would be a loan through the Water Development Program funded from Coal Severance Tax Bond proceeds. This program is administered through the Montana Department of Natural Resources and Conservation, Water Resources Division. Interest rates may be reduced below the rates at which the bonds are sold if financial feasibility and need is demonstrated. However, it is likely that the M&I users will be required to repay the full interest rate plus the cost of underwriting the bonds. Repayment periods can be as long as 40 years but terms of 20 years are more likely in the bond market. Bonds have recently been sold at a 10.26% interest rate plus a one-time underwriting cost of 1 to 1-1/2%.

As developed in the Project Evaluation chapter, the public recreational benefit of Hyalite Reservoir equals a discounted value of $1,117,529 over the 40-year life of the loan. Given the importance of recreation to this area, it is suggested that a large portion of this value should be contributed as grant monies by the state and federal agencies toward the total project cost. The funds would originate from at least three sources: 1) a grant under the Small Reclamation Projects Act, 2) a land and Water Conservation Fund grant administered by the Montana Department of Fish, Wildlife and Parks, and 3) a grant through the DNRC Water Development Fund. It is suggested that the grant(s) be allocated as necessary to agriculture to keep the loan repayment within the "willingness to pay" amounts and within the $35/AF least cost alternative for M&I. If the grant is not made available, M&I users would have to pick up a portion of the irrigation principal or the scope of project would have to be reduced. A state grant of $496,000 and a federal grant of $470,000 is suggested.

Allocation of Project Costs

Repayment of loan amounts will be derived by assessments by the Middle Creek Water Users Association (MCWUA). The MCWUA will in turn make a payment to the Montana Department of Natural Resources and Conservation (DNRC). The DNRC will contract for the loan or bond repayment and will secure the loan in the name of the MCWUA, through individual water purchase contracts. The MCWUA shall levy assessments necessary to operate and maintain the dam and to maintain an adequate reserve account.

Two types of assessments will be made at two different rates. First, users falling into the category of municipal (M&I) will be required to repay their allocated costs with interest. The agricultural users will be required to make a principal payment only. Allocation of costs will be made on the basis of water delivered on an annual basis. As shown in the payout schedule, Table IX.3, it is assumed that all 10,184 AF can be contracted by the MCWUA in Year One with the majority of the water going to agriculture. All of the newly contracted water (2,334 AF) will be optioned for ultimate M&I use. That increment of new storage not needed for M&I use will be contracted to agriculture on a year-to-year basis at the agricultural rate. It is assumed that as the City of Bozeman grows, more water will be contracted. For purposes of the payout schedule, this process was assumed to occur uniformly over the 40-year repayment period. Water contracts presently held by agriculture (5,005 AF) were assumed to be reserved for long-term contracts.

Given the above assumptions, approximately 60% of the water will be consumed by agriculture and 40% consumed by M&I over a 40-year period. However, a third nonconsumptive use, recreation, must be considered in allocation of costs for

purposes of a Federal Recreational Grant under the Small Loans Program. Recreation is defined herein as boating, fishing, camping, picnicking and hiking activities. Cost allocations are made by use of the Separable Costs-Remaining Benefits method as shown in Table IX.1. This table is simplified from those typically prepared as there are no separable costs associated with this project. For agriculture and M&I water the single-purpose alternative cost is $35/AF as developed in Chapter VIII, Project Evaluation. As shown in Table IX.1, a grant of one-half of the recreational allocation can be made under the Small Loans Program. The exact allowance amount, by equation, is $479,200 but the grant request is rounded to $475,000.

Historically, water has been carried over in the reservoir providing recreational benefits. This operation will continue in the future and the additional storage will provide higher reservoir levels. No minimum pool is allocated to this reservoir. It is important to note that total benefits from recreation have been claimed as an unsafe dam will be breached and recreational benefits from this reservoir will be nonexistent. Incremental analysis of recreational benefits is not applicable in a dam safety analysis.

Table IX.1
Separable Costs - Remaining Benefits Allocation
8-3/8% Interest - 100 Years

Item	Irrigation, Municipal and Industrial Water Supply Consumptive Use	Recreation Non-Consumptive Use	Total
Costs to be Allocated			
Preconstruction			$ 315,000
Construction			3,836,000
IDC			295,000
OM&R			121,600
Annual Benefits	($ 356,440)[1/]	($ 97,500)	453,940
Capitalized Benefits	4,256,000	1,164,000	5,420,000
Single-Purpose Alternative	4,256,000[2/]	3,985,000[3/]	8,241,000
Justifiable Expenditure	4,256,000	1,164,000	5,420,000
Separable Costs			
Preconstruction	0	0	0
Construction	0	0	0
IDC	0	0	0
OM&R	0	0	0
Remaining Justifiable Expenditure	4,256,000	1,164,000	5,420,000
Percent Distribution	78.5	21.5	100.0
Allocated Joint Costs			
Preconstruction	247,300	67,700	315,000
Construction	3,011,000	825,000	3,836,000
IDC	231,000	64,000	295,000
OM&R	95,500	26,100	121,600

1/ (10,184 x $35/AF).
2/ Least cost alternative is $35/AF - See Chapter VIII.
3/ Minimum cost of rehabilitation, 8 ft. increase in dam height, see Figure VI-1.

Table IX.1 (continued)

Item	Irrigation, Municipal and Industrial Water Supply Consumptive Use	Recreation Non-Consumptive Use	Total
TOTAL ALLOCATED COSTS			
Preconstruction	247,300	67,700	315,000
Construction	3,011,000	825,000	3,836,000
IDC	231,000	64,000	295,000
OM&R Capitalized	95,500	26,100	121,600
Annual	(8,000)	(2,200)	(10,184)
SUBALLOCATION			
	Irrigation (59.8%)	M&I (40.2%)4/	Recreation	Total
Preconstruction	147,900	99,400	67,700	315,000
Construction	1,801,000	1,210,000	825,000	3,836,000
IDC	138,200	92,800	64,000	295,000
OM&R Annual	4,780	3,220	2,200	10,200

4/ Computed from total water use (see Table IX.3 and 4) 163,580 / 407,360 = 0.402

TABLE IX.2

Summary of Reimbursable and Non-Reimbursable Costs

Purpose & Component	Pre Const.	Const.	IDC	Annual OM&R
Reimbursable				
Irrigation	147,900	1,801,000	0	4,780
M&I	99,400	1,210,000	120,000 1/	3,220
Recreation	0	0	0 4/	2,200
Non-Reimbursable				
Irrigation	0	0	138,000	0
Recreation	67,700 2/	825,000 3/	64,000	0
TOTALS	315,000	3,836,000	322,000	10,200

1/ IDC computed @ 10-7/8% repayment rate.
2/ Cost in PL-984 grant.
3/ Cost divided evenly between PL 984 grant and the state of Montana grant.
4/ Because there is no reimbursable construction cost there would also be no reimbursable IDC.

Determination of Maximum Allowable Federal Grant

50% of Recreation Construction Costs	$412,500
100% of Recreation Preconstruction Costs	67,700
TOTAL ALLOWABLE	$479,200
AMOUNT REQUESTED	$470,000

TABLE IX.3

ANNUAL ASSESSMENT SCHEDULE ($/AF)

	With Grants		Without Grants	
	M&I	AG	M&I	AG
P.L. 984 Loan Repayment	$34.00	$4.00	$47.97	$4.00
O,M&R	1.00	1.00	1.00	1.00
Existing Debt	0.00	0.00	0.00	0.00
Emergency Fund	0.00	0.00	0.00	0.00
	$35.00	$5.00	$48.97	$5.00

TABLE IX.4

PROJECT INTEREST DURING CONSTRUCTION[1/]
(8-3/8%)

Project Cost	$4,271,000
Less Preconstruction	315,000
Less IDS Estimate	120,000
	$3,836,000

Year	Expenditure	1/2 of Exp.	Total Prev. Exp.	Total Prev. Int.	Interest	Interest
1	1,540,000	770,000	0	0	770,000	64,488
2	2,296,000	1,148,000	1,540,000	64,488	2,751,488	230,520
				TOTAL		295,009
				USE		295,000

1/ This table is presented as basis for Cost Allocation at 8-3/8% discount rate - actual repayment is at 10-7/8% repayment rate.

Table IX.5

FINANCIAL PROGRAM AND PAYOUT SCHEDULE WITH GRANT SCENARIO

Economic Consultants Northwest
Middle Creek Project
February 8, 1985

Municipal Water Cost : 35.00
Loan (Less IDC,M&I) : 2874030
Capital Recovery Factor: .1105288
OMR Factor : 1
Interest During Constr : 300000

Ag Water Cost : 5.00
Interest Rate : .10875
Discount Rate : .08375
Starting year : 1988
N : 40

			Sales			O M & R			Revenues				Expenses									Municipal					
N	Year	Ag	Municpal	total	Ag	Municipal	total	Ag	Small Tract	Urban	total	Ag	Municipal	total	Reserve Balance	Existing Debt	Municipal Portion	Municipal IDC	Net Municipal	Balance Beginning	Total	Interest	Principal	Ag Principal	Total Principal	Total Loan Payment
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)
1	1988	7184.0	3000.0	10184	7184	3000	10184	35920	6195	98805	140920	7184	3000	10184	25000	255	.295	9768	102000	2874030	92232	92071	161	28481	28642	130481
2	1989	7128.1	3055.9	10184	7128	3056	10184	35641	6195	100761	142596	7128	3056	10184	25000	176	.200	9950	103900	2845388	93950	92851	1099	28337	29435	132236
3	1990	7072.3	3111.7	10184	7072	3112	10184	35361	6195	102716	144272	7072	3112	10184	25000	59	.506	10132	105799	2815953	95668	93571	2097	28230	30327	134029
4	1991	7016.4	3167.6	10184	7016	3168	10184	35082	6195	104672	145948	7016	3168	10184	25000	59	.311	10314	107699	2785626	97385	94225	3160	28007	31167	135705
5	1992	6960.5	3223.5	10184	6961	3223	10184	34803	6195	106627	147625	6961	3223	10184	25000	59	.317	10496	109599	2754459	99103	94814	4289	27783	32072	137382
6	1993	6904.6	3279.4	10184	6905	3279	10184	34523	6195	108583	149301	6905	3279	10184	25000	59	.322	10677	111498	2722387	100821	95334	5486	27560	33046	139058
7	1994	6843.8	3335.2	10184	6849	3335	10184	34244	6195	110538	150977	6849	3335	10184	25000	59	.327	10859	113398	2689341	102539	95782	6757	27336	34093	140734
8	1995	6792.9	3391.1	10184	6793	3391	10184	33964	6195	112494	152653	6793	3391	10184	25000	39	.333	11041	115298	2655248	104256	96152	8105	27133	35237	142430
9	1996	6737.0	3447.0	10184	6737	3447	10184	33685	6195	114449	154329	6737	3447	10184	25000	0	.338	11223	117197	2620011	105974	96439	9535	26948	36483	144145
10	1997	6681.2	3502.8	10184	6681	3503	10184	33406	6195	116405	156005	6681	3503	10184	25000	0	.344	11405	119097	2583528	107692	96637	11054	26725	37779	145821
11	1998	6625.3	3558.7	10184	6625	3559	10184	33126	6195	118360	157682	6625	3559	10184	25000	0	.349	11587	120996	2545749	109409	96743	12666	26501	39167	147498
12	1999	6569.4	3614.6	10184	6569	3615	10184	32847	6195	120316	159358	6569	3615	10184	25000	0	.355	11769	122896	2506582	111127	96750	14377	26278	40655	149174
13	2000	6513.5	3670.5	10184	6514	3670	10184	32568	6195	122271	161034	6514	3670	10184	25000	0	.360	11951	124796	2465927	112845	96652	16193	26054	42247	150850
14	2001	6457.7	3726.3	10184	6458	3726	10184	32288	6195	124227	162710	6458	3726	10184	25000	0	.366	12133	126695	2423680	114563	96442	18120	25831	43951	152526
15	2002	6401.8	3782.2	10184	6402	3782	10184	32009	6195	126182	164386	6402	3782	10184	25000	0	.371	12315	128595	2379730	116280	96113	20167	25607	45774	154202
16	2003	6345.9	3838.1	10184	6346	3838	10184	31730	6195	128138	166062	6346	3838	10184	25000	0	.377	12497	130495	2333955	117998	95657	22341	25384	47725	155878
17	2004	6290.0	3894.0	10184	6290	3894	10184	31450	6195	130093	167739	6290	3894	10184	25000	0	.382	12679	132594	2286231	119716	95065	24651	25160	49811	157555
18	2005	6234.2	3949.8	10184	6234	3950	10184	31171	6195	132049	169415	6234	3950	10184	25000	0	.388	12860	134294	2236420	121434	94328	27105	24937	52042	159231
19	2006	6178.3	4005.7	10184	6178	4006	10184	30892	6195	134004	171091	6178	4006	10184	25000	0	.393	13042	136194	2184378	123151	93437	29715	24713	54428	160907
20	2007	6122.4	4061.6	10184	6122	4062	10184	30612	6195	135960	172767	6122	4062	10184	25000	0	.399	13224	138093	2129950	124869	92379	32490	24490	56980	162583
21	2008	6066.6	4117.4	10184	6067	4117	10184	30333	6195	137915	174443	6067	4117	10184	25000	0	.404	13406	139993	2072970	126587	91145	35442	24266	59708	164259
22	2009	6010.7	4173.3	10184	6011	4173	10184	30053	6195	139871	176119	6011	4173	10184	25000	0	.410	13588	141893	2013262	128304	89721	38584	24043	62627	165935
23	2010	5954.8	4229.2	10184	5955	4229	10184	29774	6195	141826	177796	5955	4229	10184	25000	0	.415	13770	143792	1950635	130022	88093	41929	23819	65748	167612
24	2011	5898.9	4285.1	10184	5899	4285	10184	29495	6195	143782	179472	5899	4285	10184	25000	0	.421	13952	145692	1884887	131740	86249	45491	23596	69087	169288
25	2012	5843.1	4340.9	10184	5843	4341	10184	29215	6195	145737	181148	5843	4341	10184	25000	0	.426	14134	147592	1815800	133458	84171	49287	23372	72659	170964
26	2013	5787.2	4396.8	10184	5787	4397	10184	28936	6195	147693	182824	5787	4397	10184	25000	0	.432	14316	149491	1743141	135175	81843	53333	23149	76481	172640
27	2014	5731.3	4452.7	10184	5731	4453	10184	28657	6195	149649	184500	5731	4453	10184	25000	0	.437	14498	151591	1666660	136893	79246	57647	22925	80572	174316
28	2015	5675.5	4508.5	10184	5675	4509	10184	28377	6195	151604	186176	5675	4509	10184	25000	0	.443	14680	153290	1586088	138611	76361	62249	22702	84951	175992
29	2016	5619.6	4564.4	10184	5620	4564	10184	28098	6195	153560	187852	5620	4564	10184	25000	0	.448	14862	155190	1501136	140329	73167	67161	22478	89640	177668
30	2017	5563.7	4620.3	10184	5564	4620	10184	27819	6195	155515	189529	5564	4620	10184	25000	0	.454	15043	157090	1411497	142046	69640	72406	22255	94661	179345
31	2018	5507.8	4676.2	10184	5508	4676	10184	27539	6195	157471	191205	5508	4676	10184	25000	0	.459	15225	158989	1316835	143764	65755	78009	22031	100040	181021
32	2019	5452.0	4732.0	10184	5452	4732	10184	27260	6195	159426	192881	5452	4732	10184	25000	0	.465	15407	160889	1216795	145482	61486	83996	21808	105804	182697
33	2020	5396.1	4787.9	10184	5396	4788	10184	26980	6195	161382	194557	5396	4788	10184	25000	0	.470	15589	162789	1110992	147200	56802	90397	21584	111981	184373
34	2021	5340.2	4843.8	10184	5340	4844	10184	26701	6195	163337	196233	5340	4844	10184	25000	0	.476	15771	164688	999010	148917	51673	97244	21361	118605	186049
35	2022	5284.4	4899.6	10184	5284	4900	10184	26422	6195	165293	197909	5284	4900	10184	25000	0	.481	15953	166588	880405	150635	46064	104571	21137	125709	187725
36	2023	5228.5	4955.5	10184	5228	4956	10184	26142	6195	167248	199586	5228	4956	10184	25000	0	.487	16135	168488	754697	152353	39937	112416	20914	133330	189402
37	2024	5172.6	5011.4	10184	5173	5011	10184	25863	6195	169204	201262	5173	5011	10184	25000	0	.492	16317	170387	621367	154070	33252	120819	20690	141509	191078
38	2025	5116.7	5067.3	10184	5117	5067	10184	25584	6195	171159	202938	5117	5067	10184	25000	0	.498	16499	172237	479858	155788	25966	129823	20467	150290	192754
39	2026	5060.9	5123.1	10184	5061	5123	10184	25304	6195	173115	204614	5061	5123	10184	25000	0	.505	16681	174187	329568	157506	18030	139476	20243	159720	194430
40	2027	5005.0	5179.0	10184	5005	5179	10184	25025	6195	175070	206290	5005	5179	10184	25000	0	.509	16863	176086	169849	159224	9393	149830	20018	169849	196104
totals		243779.84	163580.16	407360	243780	163580	407360	1218899	247800	5477506	6944205	243780	163580	407360	25000			532610	5561725		5029116	3129438	1899677	974353	2874030	6536078

Discount Total Payments: 1695186

Table IX.5

FINANCIAL PROGRAM AND PAYOUT SCHEDULE WITH GRANT SCENARIO

Economic Consultants Northwest
Middle Creek Project
February 8, 1985

Municipal Water Cost	:	35.00	
Loan (Less IDC,Mkt)	:	2874030	
Capital Recovery Factor	:	.1105288	
OMR Factor	:	1	
Interest During Constr	:	300000	
Ag Water Cost	:	5.00	
Interest Rate	:	.10875	
Discount Rate	:	.08375	
Starting year	:	1988	
N	:	40	

		Sales			O M & R			Revenues				Expenses								Municipal			Ag	Total	Total Loan
N	Year	Ag	Municipal	Total	Ag	Municipal	Total	Ag	Small Tract	Urban	Total	Ag	Municipal	Total	Reserve Balance	Existing Debt	Municipal Portion	Municipal IDC	Net Municipal	Balance Beginning	Total	Interest	Principal	Principal	Principal	Payments
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)
1	1988	7184.0	3000.0	10184	7184	3000	10184	35920	6195	98805	140920	7184	3000	10184	25000	255	.295	9768	102000	2874030	92232	92071	161	28481	28642	130481
2	1989	7128.1	3055.9	10184	7128	3056	10184	35641	6195	100761	142596	7128	3056	10184	25000	176	.300	9950	103900	2845388	93950	92851	1099	28337	29435	132236
3	1990	7072.3	3111.7	10184	7072	3112	10184	35361	6195	102716	144272	7072	3112	10184	25000	59	.306	10132	105799	2815953	95668	93571	2097	28230	30327	134029
4	1991	7016.4	3167.6	10184	7016	3168	10184	35082	6195	104672	145948	7016	3168	10184	25000	59	.311	10314	107699	2785626	97385	94225	3160	28007	31167	135705
5	1992	6960.5	3223.5	10184	6961	3223	10184	34803	6195	106627	147625	6961	3223	10184	25000	59	.317	10496	109599	2754459	99103	94814	4289	27783	32072	137382
6	1993	6904.6	3279.4	10184	6905	3279	10184	34523	6195	108583	149301	6905	3279	10184	25000	59	.322	10677	111498	2722387	100821	95334	5486	27560	33046	139058
7	1994	6848.8	3335.2	10184	6849	3335	10184	34244	6195	110538	150977	6849	3335	10184	25000	59	.327	10859	113398	2689341	102539	95782	6757	27336	34093	140734
8	1995	6792.9	3391.1	10184	6793	3391	10184	33964	6195	112494	152653	6793	3391	10184	25000	39	.333	11041	115298	2655248	104256	96152	8105	27133	35237	142430
9	1996	6737.0	3447.0	10184	6737	3447	10184	33685	6195	114449	154329	6737	3447	10184	25000	0	.338	11223	117197	2620011	105974	96439	9535	26948	36483	144145
10	1997	6681.2	3502.8	10184	6681	3503	10184	33406	6195	116405	156005	6681	3503	10184	25000	0	.344	11405	119097	2583528	107692	96637	11054	26725	37779	145821
11	1998	6625.3	3558.7	10184	6625	3559	10184	33126	6195	118360	157682	6625	3559	10184	25000	0	.349	11587	120996	2545749	109409	96743	12666	26501	39167	147498
12	1999	6569.4	3614.6	10184	6569	3615	10184	32847	6195	120316	159358	6569	3615	10184	25000	0	.355	11769	122896	2506582	111127	96750	14377	26278	40655	149174
13	2000	6513.5	3670.5	10184	6514	3670	10184	32568	6195	122271	161034	6514	3670	10184	25000	0	.360	11951	124796	2465927	112845	96652	16193	26054	42247	150950
14	2001	6457.7	3726.3	10184	6458	3726	10184	32288	6195	124227	162710	6458	3726	10184	25000	0	.366	12133	126695	2423680	114563	96442	18120	25831	43951	152526
15	2002	6401.8	3782.2	10184	6402	3782	10184	32009	6195	126182	164386	6402	3782	10184	25000	0	.371	12315	128595	2379730	116280	96113	20167	25607	45774	154202
16	2003	6345.9	3838.1	10184	6346	3838	10184	31730	6195	128138	166062	6346	3838	10184	25000	0	.377	12497	130495	2333955	117998	95657	22341	25384	47725	155878
17	2004	6290.0	3894.0	10184	6290	3894	10184	31450	6195	130093	167739	6290	3894	10184	25000	0	.382	12679	132394	2286231	119716	95065	24651	25160	49811	157555
18	2005	6234.2	3949.8	10184	6234	3950	10184	31171	6195	132049	169415	6234	3950	10184	25000	0	.388	12860	134294	2236420	121434	94328	27105	24937	52042	159231
19	2006	6178.3	4005.7	10184	6178	4006	10184	30892	6195	134004	171091	6178	4006	10184	25000	0	.393	13042	136194	2184378	123151	93437	29715	24713	54428	160907
20	2007	6122.4	4061.6	10184	6122	4062	10184	30612	6195	135960	172767	6122	4062	10184	25000	0	.399	13224	138093	2129950	124869	92379	32490	24490	56980	162583
21	2008	6066.6	4117.4	10184	6067	4117	10184	30333	6195	137915	174443	6067	4117	10184	25000	0	.404	13406	139993	2072970	126587	91145	35442	24266	59708	164259
22	2009	6010.7	4173.3	10184	6011	4173	10184	30053	6195	139871	176119	6011	4173	10184	25000	0	.410	13588	141893	2013262	128304	89721	38584	24043	62627	165935
23	2010	5954.8	4229.2	10184	5955	4229	10184	29774	6195	141826	177796	5955	4229	10184	25000	0	.415	13770	143792	1950635	130022	88093	41929	23819	65748	167612
24	2011	5898.9	4285.1	10184	5899	4285	10184	29495	6195	143782	179472	5899	4285	10184	25000	0	.421	13952	145692	1884387	131740	86249	45491	23596	69087	169288
25	2012	5843.1	4340.9	10184	5843	4341	10184	29215	6195	145737	181148	5843	4341	10184	25000	0	.426	14134	147592	1815800	133458	84171	49287	23372	72659	170964
26	2013	5787.2	4396.8	10184	5787	4397	10184	28936	6195	147693	182824	5787	4397	10184	25000	0	.432	14316	149491	1743141	135175	81843	53333	23149	76481	172640
27	2014	5731.3	4452.7	10184	5731	4453	10184	28657	6195	149649	184500	5731	4453	10184	25000	0	.437	14498	151391	1666660	136893	79246	57647	22925	80572	174316
28	2015	5675.5	4508.5	10184	5675	4509	10184	28377	6195	151604	186176	5675	4509	10184	25000	0	.443	14680	153290	1586038	138611	76361	62249	22702	84951	175992
29	2016	5619.6	4564.4	10184	5620	4564	10184	28098	6195	153560	187852	5620	4564	10184	25000	0	.448	14862	155190	1501136	140329	73167	67161	22478	89640	177668
30	2017	5563.7	4620.3	10184	5564	4620	10184	27819	6195	155515	189529	5564	4620	10184	25000	0	.454	15043	157090	1411497	142046	69640	72406	22255	94661	179345
31	2018	5507.8	4676.2	10184	5508	4676	10184	27539	6195	157471	191205	5508	4676	10184	25000	0	.459	15225	158989	1316835	143764	65755	78009	22031	100040	181021
32	2019	5452.0	4732.0	10184	5452	4732	10184	27260	6195	159426	192881	5452	4732	10184	25000	0	.465	15407	160889	1216795	145482	61486	83996	21808	105804	182697
33	2020	5396.1	4787.9	10184	5396	4788	10184	26980	6195	161382	194557	5396	4788	10184	25000	0	.470	15589	162789	1110992	147200	56802	90397	21584	111981	184373
34	2021	5340.2	4845.8	10184	5340	4844	10184	26701	6195	163337	196233	5340	4844	10184	25000	0	.476	15771	164688	999010	148917	51673	97244	21361	118605	186049
35	2022	5284.4	4899.6	10184	5284	4900	10184	26422	6195	165293	197909	5284	4900	10184	25000	0	.481	15955	166588	880405	150635	46064	104571	21137	125709	187725
36	2023	5228.5	4955.5	10184	5228	4956	10184	26142	6195	167248	199586	5228	4956	10184	25000	0	.487	16135	168488	754697	152353	39937	112416	20914	133330	189402
37	2024	5172.6	5011.4	10184	5173	5011	10184	25863	6195	169204	201262	5173	5011	10184	25000	0	.492	16317	170387	621367	154070	33252	120819	20690	141509	191078
38	2025	5116.7	5067.3	10184	5117	5067	10184	25584	6195	171159	202938	5117	5067	10184	25000	0	.498	16499	172287	479858	155788	25966	129823	20467	150290	192754
39	2026	5060.9	5123.1	10184	5061	5123	10184	25304	6195	173115	204614	5061	5123	10184	25000	0	.503	16681	174187	329568	157506	13030	139476	20243	159720	194430
40	2027	5005.0	5179.0	10184	5005	5179	10184	25025	6195	175070	206290	5005	5179	10184	25000	0	.509	16863	176086	169849	159224	9393	149830	20018	169848	196104
Totals		243779.84	163580.16	407360	243780	163580	407360	1218899	247800	5477506	6944205	243780	163580	407360	25000			532610	5561725		5029116	3129438	1899677	974353	2874030	6536078

Discount Total Payments: 1695186

Column Descriptions - Payout Schedule

Column 1	-	Year of repayment.
Column 2	-	Calendar year if funds become available on schedule.
Column 3	-	Amount of water available for sale for commercial agriculture - supplemental irrigation
Column 4	-	Amount of water projected for M&I use.
Column 5	-	Total of Columns 3 and 4.
Columns 6, 7 and 8	-	O,M&R assessment at $1.00/AF of water sold.
Column 9	-	Revenue from irrigation assessment. Based on $5.00/AF times Column 3.
Column 10, and 11	-	Revenue required from M&I sources (small tracts, i.e., 10 acres or less and urban, i.e., City of Bozeman) to repay the portion of the loan allocated to M&I purposes and to pay other M&I costs. Set at $35/AF with grant scenario, derived value without grant.
Column 12,	-	Total revenue equals the sum of Columns 9 and 10.
Column 13,14 and 15	-	Expenses in this case are equal to O,M&R assessments.
Column 16	-	An emergency reserve fund of $25,000 presently exists and will be maintained.
Column 17	-	Existing debt based on payments due on unpaid contracts starting in 1988 at $1.96/AF.
Column 18	-	M&I portion of loan which bears interest - Column 4 divided by Column 5.

Column 19	-	M&I portion of Interest During Construction which must be repaid with interest - Based on Column 17 times Total IDC times Capital Recovery Factor (0.11053).
Column 20	-	Municipal payment available to be applied to loan principal and interest (Column 10 minus Column 13).
Column 21	-	Principal balance of loan at beginning of year - Calculated by subtracting previous year principal payment (Column 25) from previous year beginning balance (Column 20).
Column 22	-	Amount available for loan principal and interest payment (Column 19 minus Column 18).
Column 23	-	Interest bearing portion of loan - Column 17 times Column 20 times interest rate (10-7/8%).
Column 24	-	Principal payment - Column 21 minus Column 22.
Column 25	-	Agricultural principal payment without interest based on $5.00/AF "willingness to pay" (Column 9 minus Columns 12 and 16).
Column 26	-	Column 23 plus Column 24.
Column 27	-	Column 18 plus Column 21 plus Column 24.

EXHIBIT A

A-1 THROUGH A-10

PROPOSED PLANS

1. LABRYINTH WIER
2. EXISTING PRINCIPAL SPILLWAY REHABILITATION
3. SPILLWAY CHANNEL ENLARGEMENT
4. SPILLWAY CHANNEL DIKE
5. BAFFLED APRON DROP
6. OUTLET CHANNEL RIPRAP
7. AUXILIARY SPILLWAY EXCAVATION
8. REINFORCED EARTH DAM ENLARGEMENT (10 FT. HEIGHT INCREASE)
9. CAMPGROUND RELOCATION
10. DAY USE AREA IMPROVEMENTS
11. ROAD RECLAMATION
12. AUXILIARY SPILLWAY TRAINING DIKE
13. ROAD RELOCATION
14. IMPERVIOUS BARRIER TRENCH AND SEEPAGE DRAIN
15. NEW EMBANKMENT FILL WITH RIPRAP ON UPSTREAM SLOPE
16. COLLECTOR DRAIN AT BASE OF DOWNSTREAM FACE OF REINFORCED EARTH WALL
17. ALTERNATE BORROW AREA FOR REINFORCED EARTH-REPLACED WITH 3' THICK COMPACTED EARTH LINING FROM AUXILARY SPILLWAY EXCAVATION FOR SEEPAGE CONTROL

1 = 100 scale — 100 0 100 200 feet

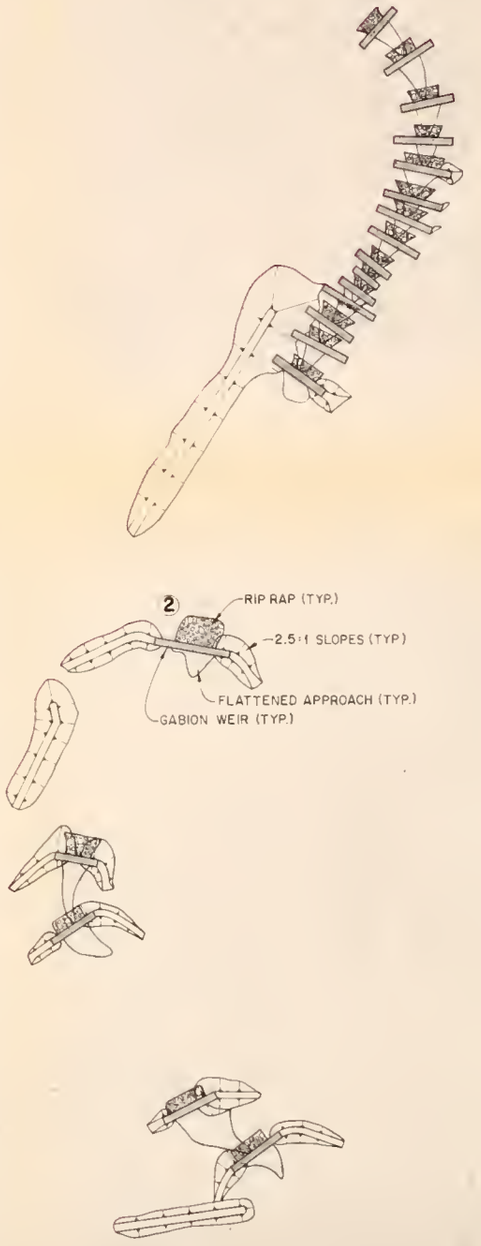
MIDDLE CREEK DAM

RECOMMENDED GENERAL SITE PLAN

8M087.113 SEPTEMBER 1984

EXHIBIT A-1

HKM ASSOCIATES ENGINEERS PLANNERS


2
RIP RAP (TYP.)
2.5:1 SLOPES (TYP.)
FLATTENED APPROACH (TYP.)
GABION WEIR (TYP.)

ALTERNATE PLANS

1. EXISTING PRINCIPAL SPILLWAY REHABILITATION
2. GABION WEIR DROP STRUCTURES
3. OUTLET CHANNEL RIPRAP
4. AUXILIARY SPILLWAY TRAINING DIKE
5. ROAD REGRADING
6. AUXILIARY SPILLWAY EXCAVATION

NO DAM HEIGHT INCREASE

1"=100' scale 100 0 100 200 feet

MIDDLE CREEK DAM
ALTERNATIVE GENERAL SITE PLAN
SM087.113 SEPTEMBER 1984

EXHIBIT A-2
HEM ASSOCIATES
ENGINEERS-PLANNERS

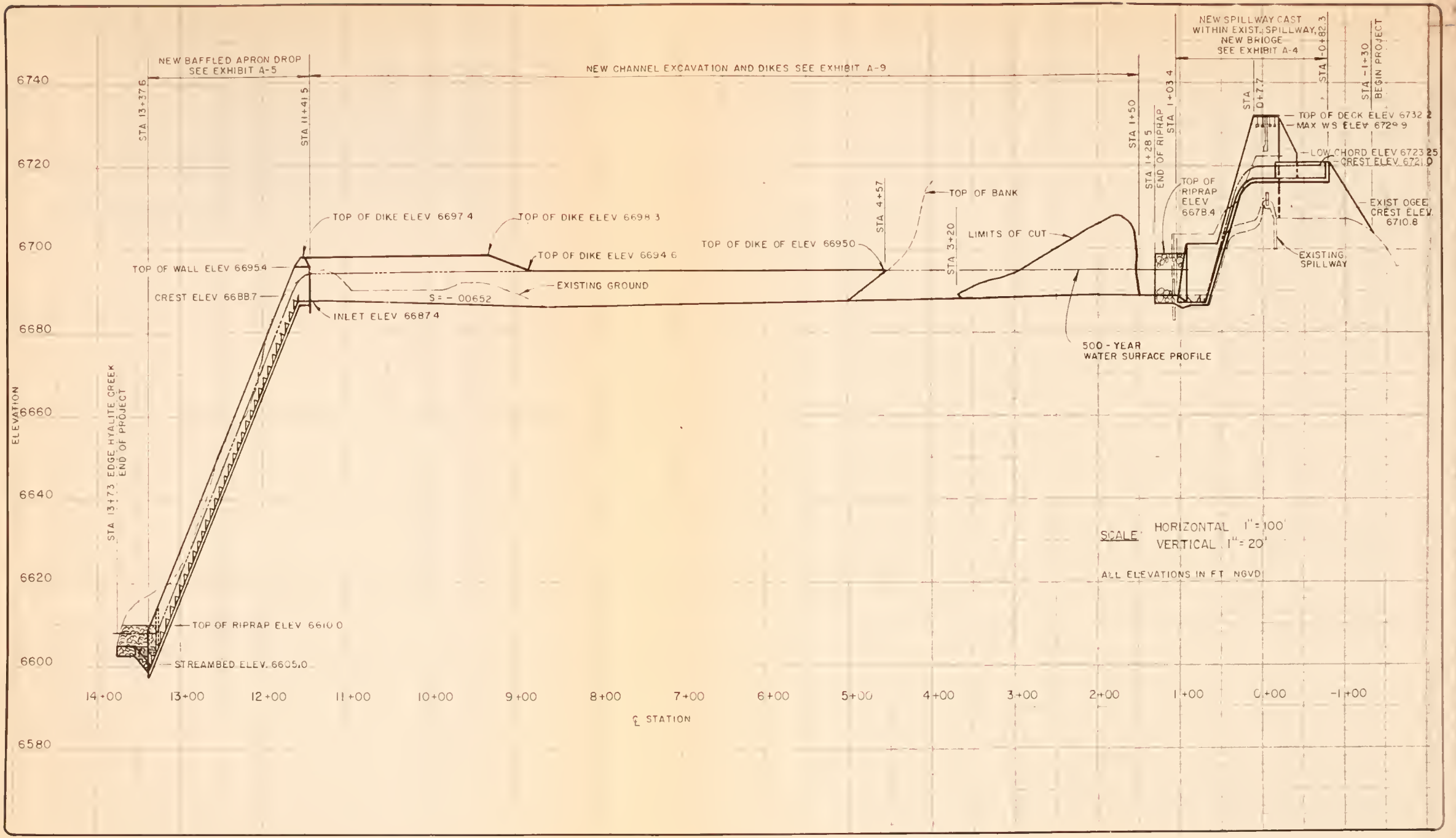


EXHIBIT A-3

HKM ASSOCIATES
ENGINEERS-PLANNERS

MIDDLE CREEK DAM REHABILITATION

PRINCIPAL SPILLWAY SYSTEM PROFILE

SEPTEMBER 1984

SM087.113

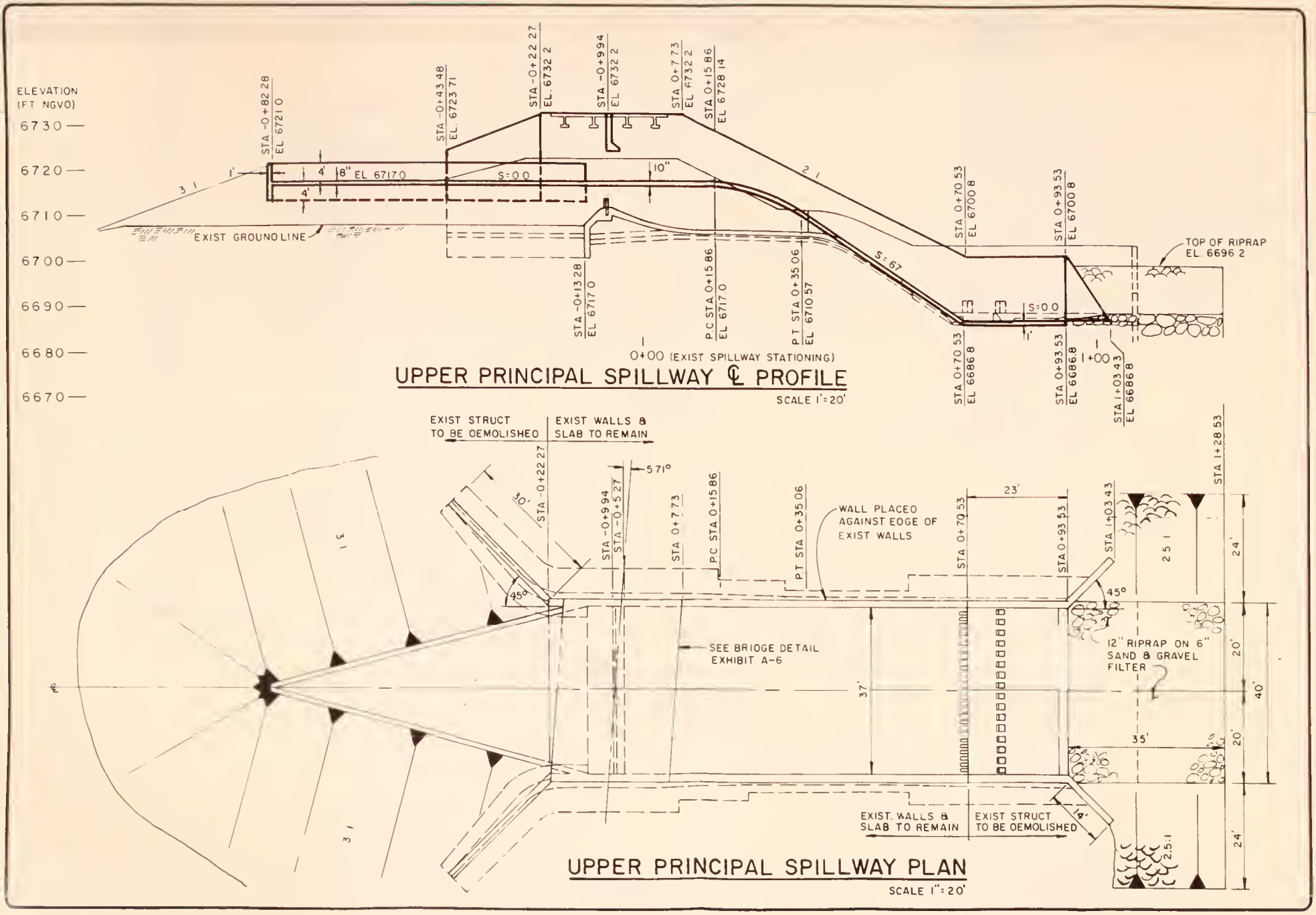


EXHIBIT A-4

HEAD ASSOCIATES
ENGINEERS PLANNERS

MIDDLE CREEK DAM REHABILITATION

EXISTING SPILLWAY REHABILITATION

SEPTEMBER 1984

8M087.113

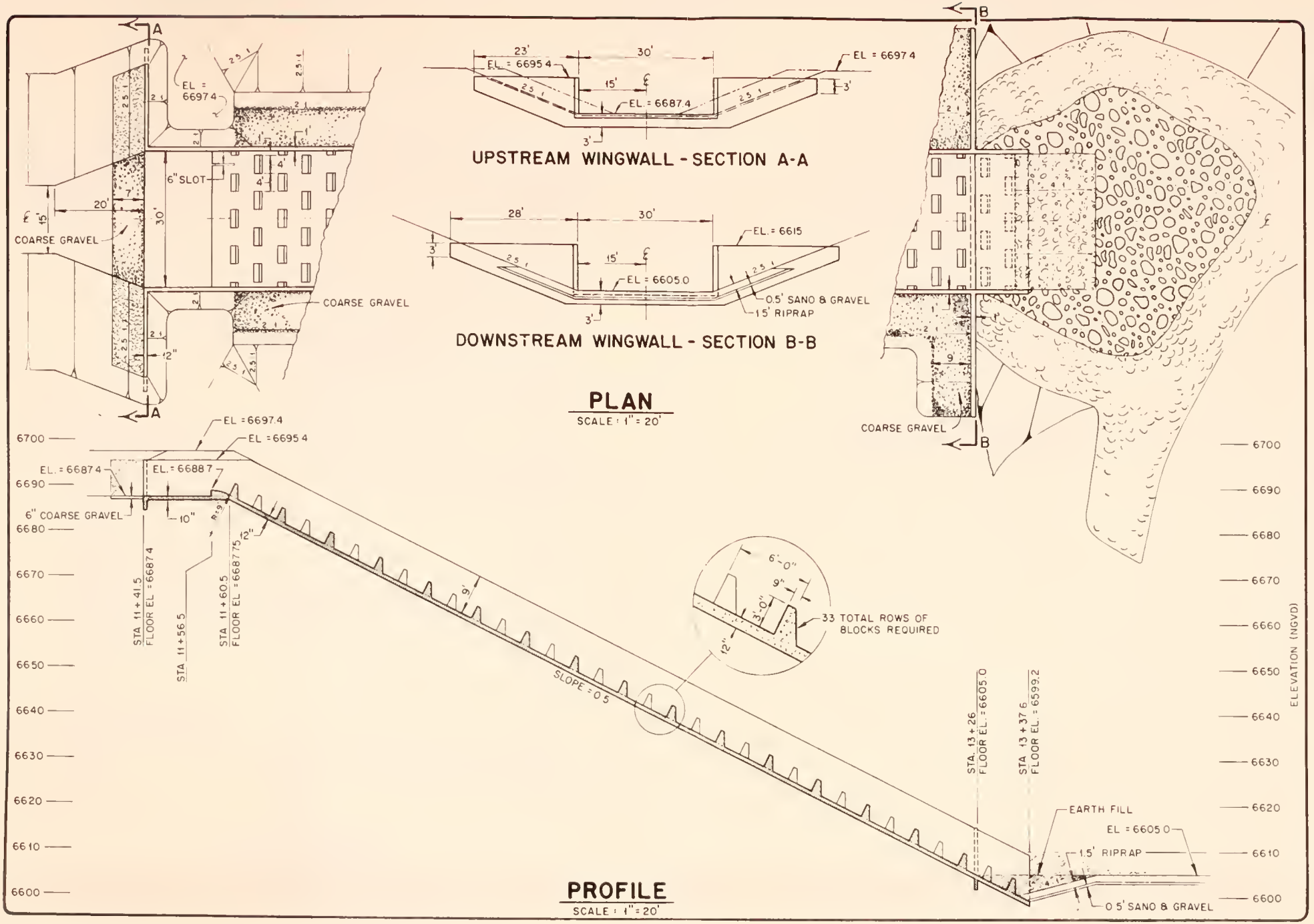


EXHIBIT A-5

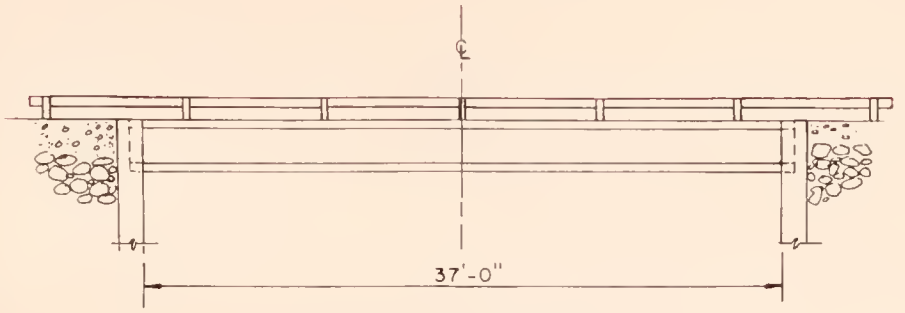
HKM ASSOCIATES
ENGINEERS-PLANNERS

MIDDLE CREEK DAM REHABILITATION

BAFFLED APRON DROP

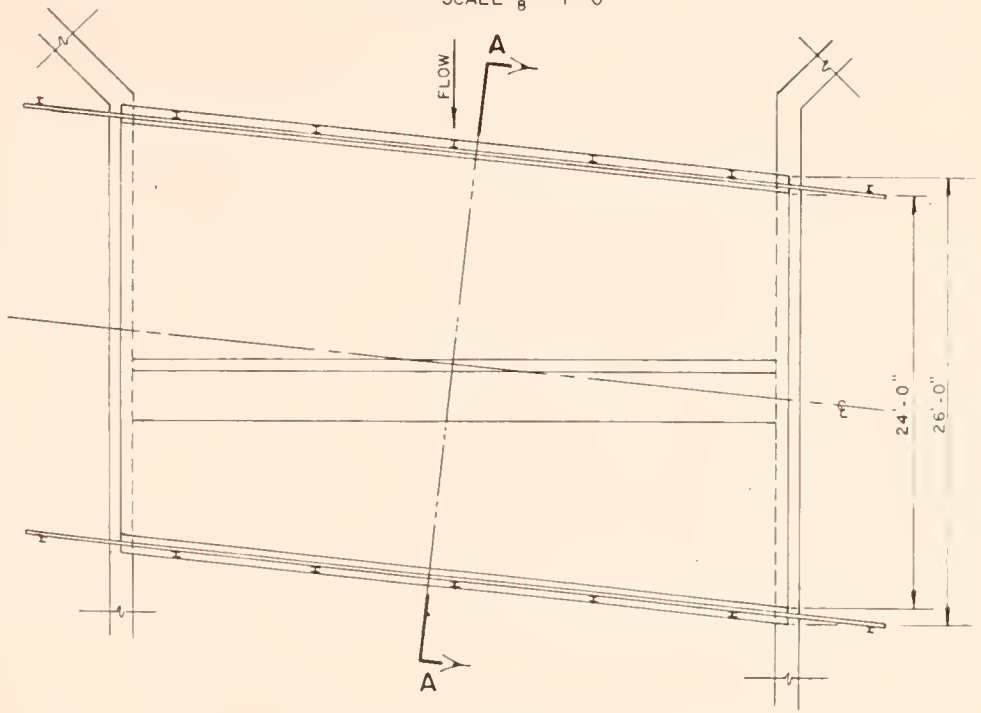
SEPTEMBER 1984

8M087.113



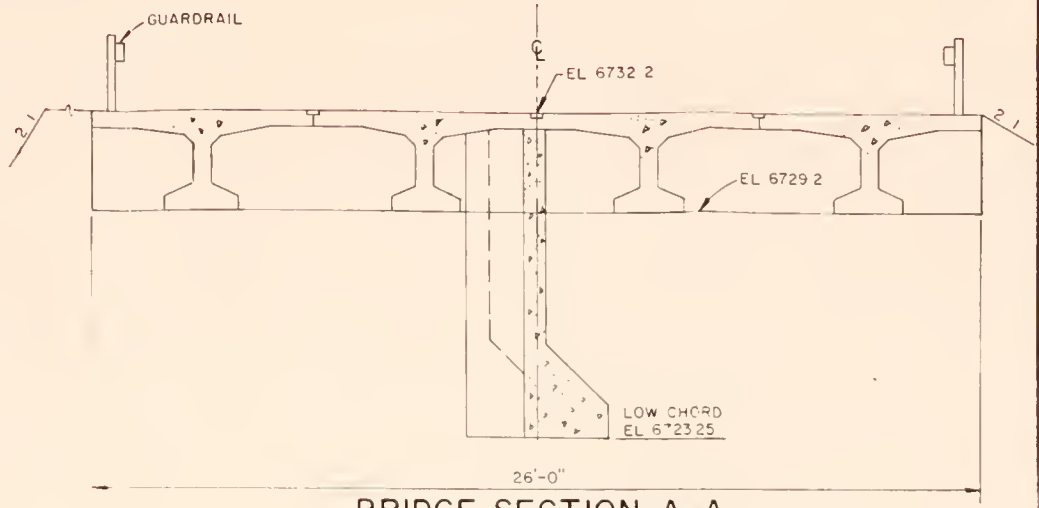
BRIDGE ELEVATION

SCALE $\frac{1}{8}$" = 1'-0"



BRIDGE PLAN

SCALE $\frac{1}{8}$" = 1'-0"



BRIDGE SECTION A-A

SCALE $\frac{1}{4}$" = 1'-0"

EXHIBIT A-6

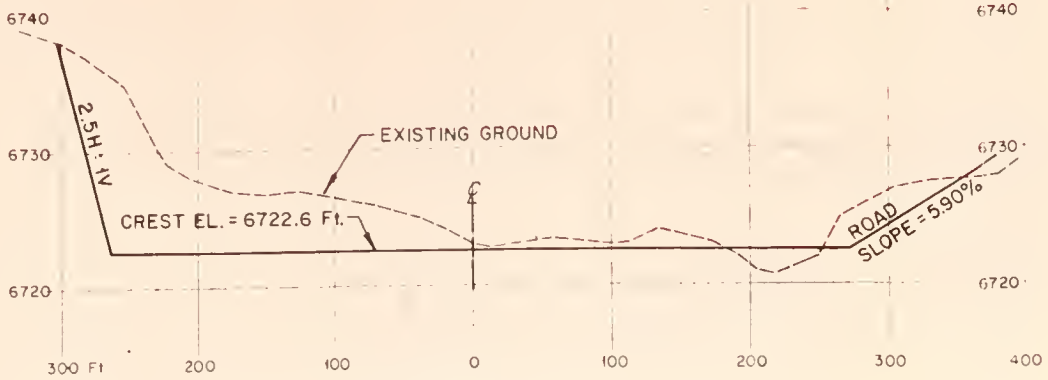
HEAM ASSOCIATES
ENGINEERS PLANNERS

MIDDLE CREEK DAM REHABILITATION

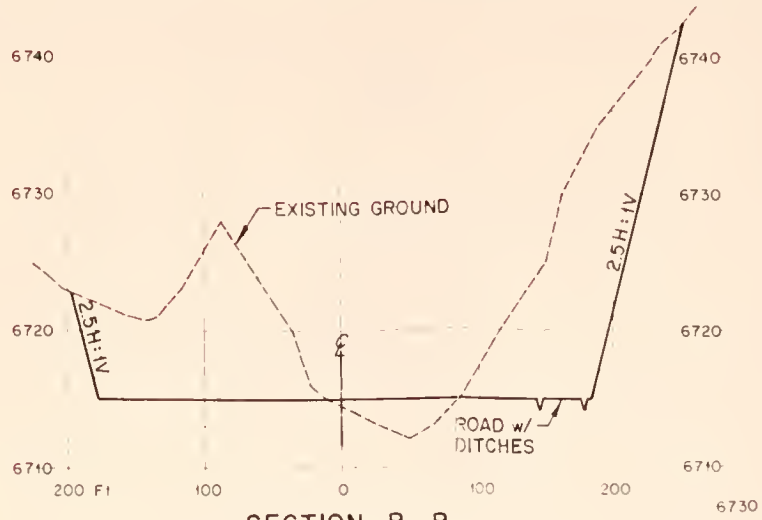
PRINCIPAL SPILLWAY BRIDGE DETAILS

SEPTEMBER 1984

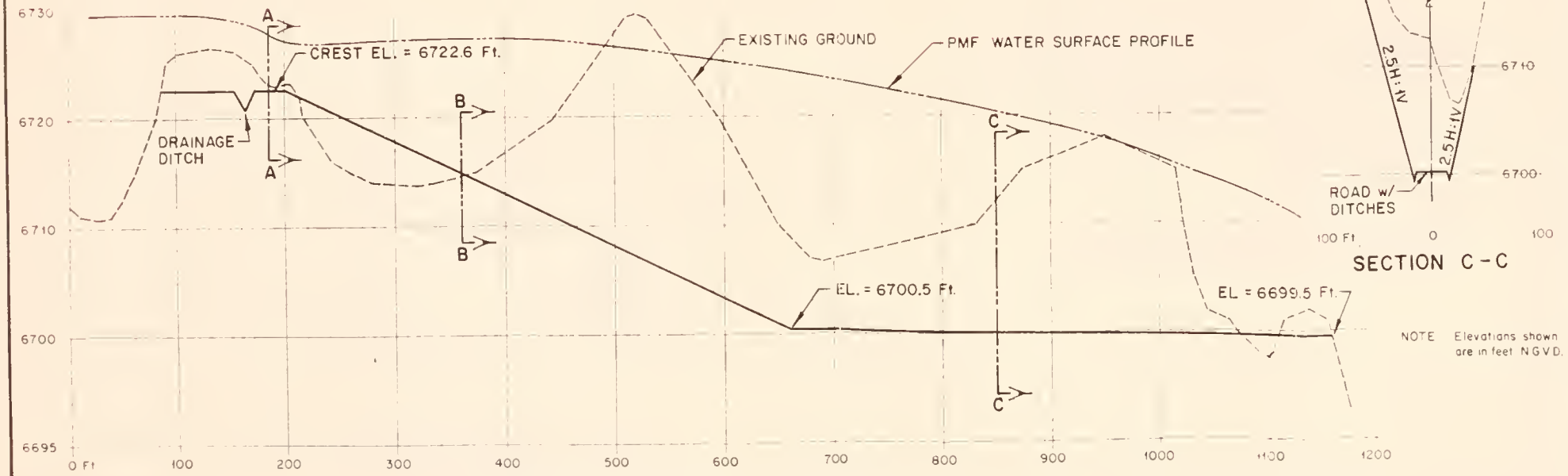
8M087.113



SECTION A-A



SECTION B-B



AUXILIARY SPILLWAY PROFILE

SECTION C-C

NOTE Elevations shown are in feet N.G.V.D.

EXHIBIT A-7

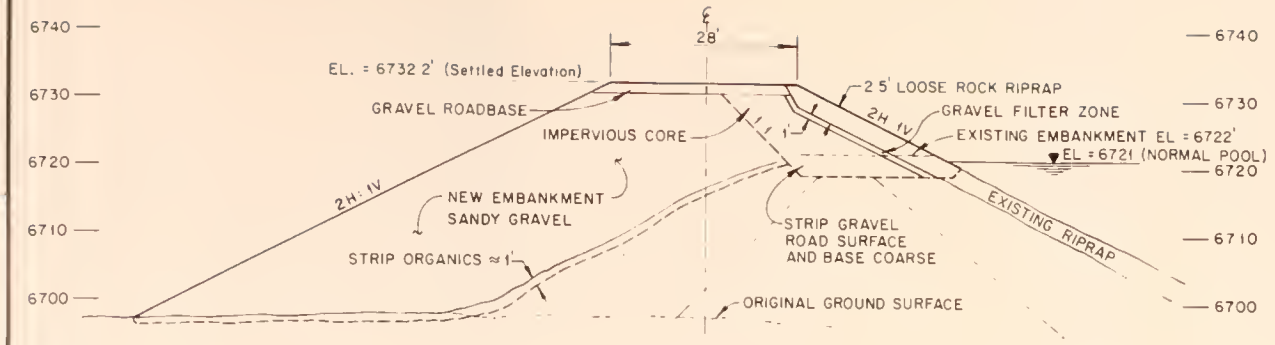
HKM ASSOCIATES
ENGINEERS PLANNERS

MIDDLE CREEK DAM REHABILITATION

AUXILIARY SPILLWAY PROFILE AND SECTIONS

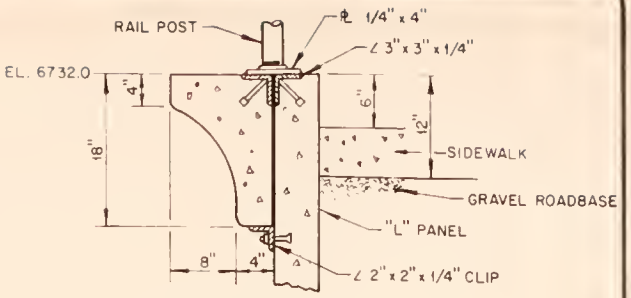
SEPTEMBER 1984

8M087.113



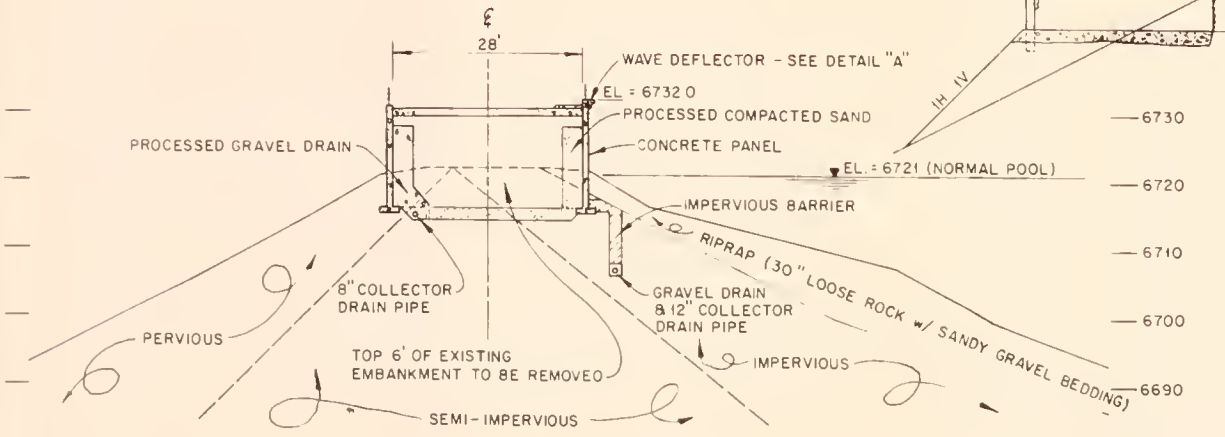
TYPICAL EMBANKMENT SECTION

SCALE : 1" = 20'



DETAIL "A" WAVE DEFLECTOR

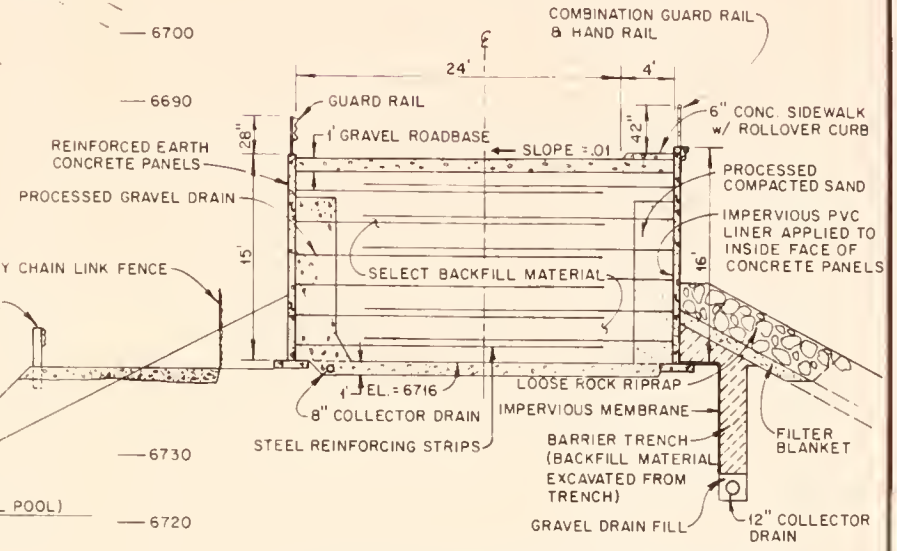
N.T.S.



TYPICAL REINFORCED EARTH SECTION

(AT MAXIMUM SECTION)

SCALE : 1" = 20'



REINFORCED EARTH SECTION DETAIL

SCALE : 1" = 10

EXHIBIT A-8

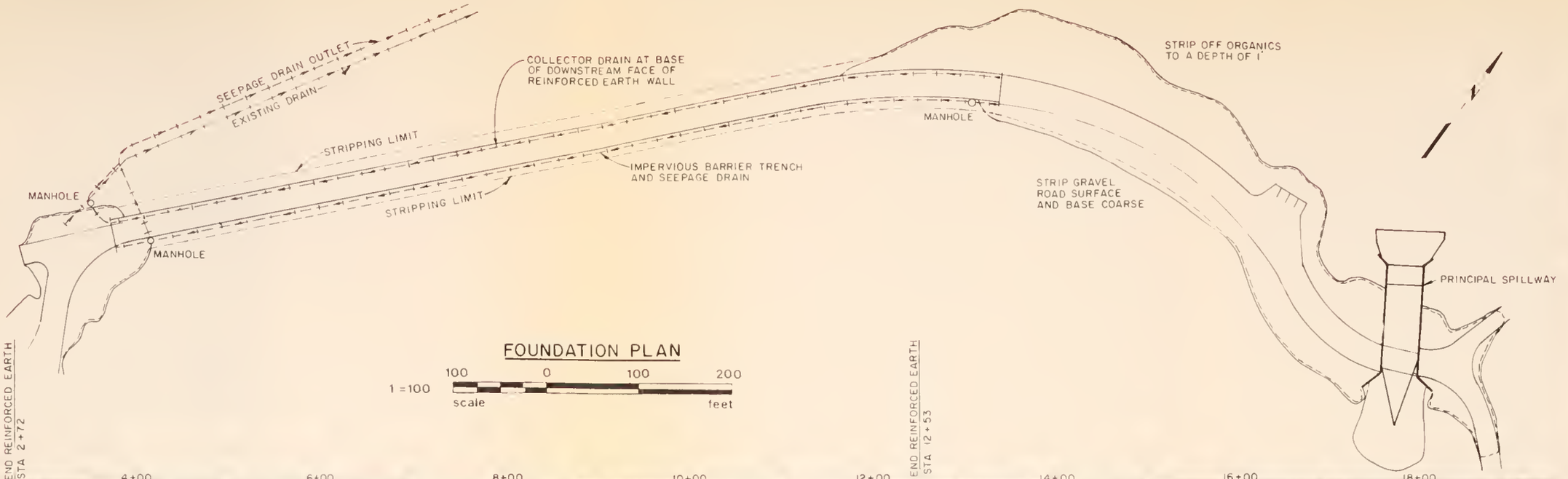
HKM ASSOCIATES
ENGINEERS/PLANNERS

MIDDLE CREEK DAM REHABILITATION

EMBANKMENT CROSS SECTIONS

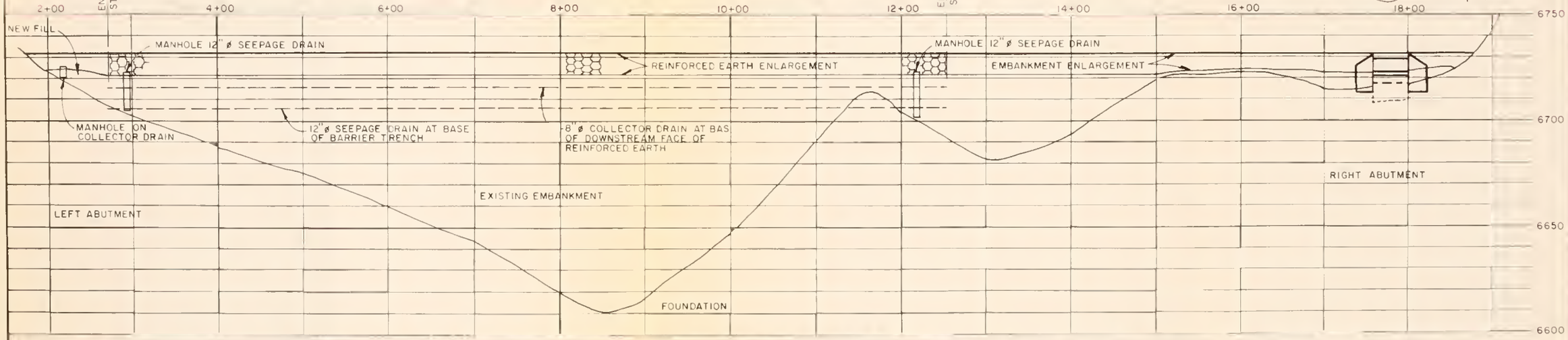
SEPTEMBER 1984

8M087.113



FOUNDATION PLAN

1 = 100 scale — 100 0 100 200 feet



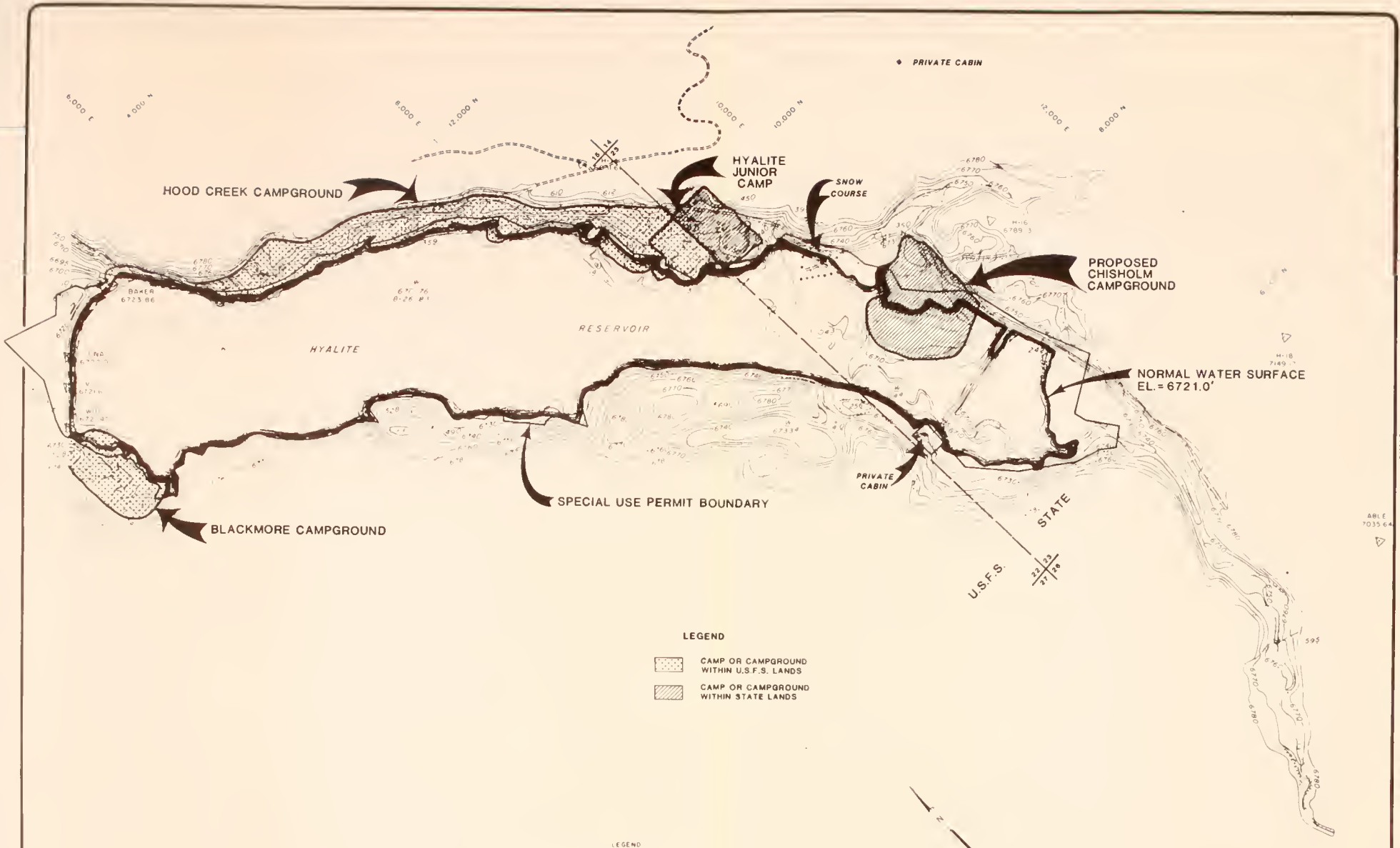
FOUNDATION PROFILE

Scale Horizontal 1" = 100'
Vertical 1" = 40'

EXHIBIT A-9
HKM ASSOCIATES ENGINEERS-PLANNERS

MIDDLE CREEK DAM REHABILITATION
FOUNDATION PLAN AND PROFILE
SEPTEMBER 1984

8M087.113



Ground Control Surveys Conducted August 1983 by NKM Associates Billings, MT

Topography Prepared From Aerial Photography August 26, 1983, 1:2,000 Associated Surveys, Inc., Billings, MT

Project No 84067.113 ID No — Date SEPT. 1984 Designed — Drawn — Checked — Approved

No	Revision	By	Date

MIDDLE CREEK DAM REHABILITATION

RESERVOIR BASIN MAP

HKM ASSOCIATES
ENGINEERS-ARCHITECTS-PLANNERS
Airport Industrial Park Branch Offices:
P.O. Box 31318 • Libby, Montana
Billings, Montana 59107 • Sheridan, Wyoming

Sheet No
EXHIBIT
A-10
of

EXHIBIT B

FARM BUDGET ANALYSIS

WORKSHEETS

Farm Budget Analysis, Financial Summary

Farm Expenses	Amount	Comments
Purchased Feed	$100.00	See Worksheet L.1
Seed and Establishment Costs	1,327.00	See Worksheet C.1
Twine	1,359.00	See Worksheet C.1
Fertilizer	7,851.00	See Worksheet C.1
Chemicals and Application	1,635.00	See Worksheet C.1
Custom Work	676.00	See Worksheet C.1
Livestock Purchase, Bulls	750.00	See Worksheet L.2
Livestock Expenses	685.00	See Worksheet O.4
Hired Labor, 102 x $3.64/hour	371.00	See Worksheet O.4
Repairs, Buildings and Improvements	1,971.00	See Worksheet O.2
Repairs, Machinery and Equipment	7,328.00	See Worksheet O.3
Depreciation, Buildings	2,464.00	See Worksheet O.2
Depreciation, Machinery	4,836.00	See Worksheet O.3
Fuel, Oil and Lubricants	7,828.00	See Worksheet O.4
Taxes, Land	1,086.00	See Worksheet O.4
Taxes, Cattle	215.00	See Worksheet O.4
Taxes, Other	3,375.00	See Worksheet O.4
Electricity	1,200.00	See Worksheet O.4
Insurance	1,000.00	See Worksheet O.4
Auto Fuel, Oil, Lube and Repairs	1,000.00	See Worksheet O.4
Interest on Operating Capital	1,443.70	See Worksheet O.4
Total, excluding water charges	$48,500.70	
Irrigation Water	300.00	See Worksheet O.4
Total, including water charges	$48,800.70	

Summary of Investment	Total Investment	Interest	Comments
Livestock	31,220.00	1,512.00	Wrksht I.1
Machinery	235,330.00	11,213.00	Wrksht I.2
Buildings and Fences	98,625.00	1,407.00	Wrksht I.3
Land	210,000.00	1,590.00	Wrksht I.4
Total Investment	575,175.00		
Interest on Investment		15,722.00	

Net Farm Income Tabulation	Amount	Comments
Crop Sales	60,080.00	See Worksheet C.2
Livestock Sales	20,310.00	See Worksheet L.2
Gross Farm Income	80,390.00	
Farm Expenses	48,500.70	
Interest on Investment	15,722.00	
Total Farm Expenses	64,222.70	
Net Farm Income	16,167.30	

Payment Capacity	subtotal	Amount	Comments
Net Farm Income		16,167.30	
Less:			
Opportunity Cost of Operator			Wrksht O.4
Labor 1/	14,624.00		Wrksht O.4
Equity Allowance	0.00		
subtotal		14,624.00	
Payment Capacity 2/			
Total		1,543.30	
Per Acre (Total Acres) Basis		3.86	

1/ The opportunity cost of operator labor is a proxy for the return to operator and family labor and management. This figure is the average annual gross earning for private nonagriculture work in Montana as reported by the Department of Labor and Industry, Helena, Montana for 1983.

2/ This payment capacity is derived from allowable return on equity and not from net farm income.

Total Variable Input Costs WS C.1

	Hay	Winter Wheat	Barley	Pasture	Total
Fertilizer	3,227	979	2,457	1,188	7,851
Custom Spread	338	135	203		676
Seed		276	488		764
Chemicals, 2,4-D		210	315	210	735
Chemicals, Fargo			900		900
Twine	1,359				1,359
Reestablishment	563				563
Total	5,487	1,600	4,363	1,398	12,848

1/ All data are from "Enterprise Costs for Irrigated Crops in Gallatin County," (Cooperative Extension Service Bulletin #1182) and are updated to 1982 prices using "Prices Paid by Farmers Index," as published in Agricultural Statistics, 1982 (USDA, 1983).

Crop Production and Disposal WS C.2

Crop	Acres	Units	Yield per Acre	Total Product	Farm Use	Quantity Sold	Sales Price 1/	Value
Alfalfa-Grass Hay	150	T	3.33	499.50	124.00	375.50	$67.50	25,346
Winter Wheat	60	BU	66.33	3,979.80	0.00	3,979.80	$4.42	17,591
Barley	90	BU	69.33	6,239.70	76.00	6,163.70	$2.70	16,642
Pasture	60	AUM	5.00	300.00	300.00	0.00	11.39	0
Summer Fallow	30							
Aftermath	300	AUM	0.30	90.00	46.00	44.00	11.39	501
Total								60,080

1/ Price data supplied by the Bureau of Reclamation.

Livestock Inventory, Production and Sales

WS L.2

Livestock	Beginning Head	Beginning Value	Purchase Head	Purchase Value	Head Born	Head Died	Head Sold	Average Weight	Total Weight	Market Price 1/	Sales Receipts
Cows	50	25,000				1	5	1000	5000	48.30	2,415
Repl Heifers	7	3,220				0	1	750	750	71.43	536
Bulls	2	3,000	0.5	750			0.5	1800	900	60.60	545
Steer Calves					24	1	23	525	12075	87.90	10,614
Heifer Calves					24	1	16	500	8000	77.50	6,200
Total	59	31,220		750							20,310

1/ Price data supplied by the Bureau of Reclamation.

Livestock Investment Costs (Primarily Interest) WS I.1

Item	Amount
Total Livestock Investment	31,220
Non-real Estate Debt:Equity Ratio	32.50%
Debt Portion	10,147
Effective Interest Rate	14.90%
subtotal	1,512
Equity Portion	21,074
Rate of Return to Equity	3.60%
subtotal	759
Total Interest	2,313

Interest on Machinery Investment WS I.2

Item	Amount
Total Machinery Investment	231,560
Non-real Estate Debt:Equity Ratio	32.50%
Debt Portion	75,257
Effective Interest Rate	14.90%
subtotal	11,213
Equity Portion	156,303
Rate of Return to Equity	3.60%
subtotal	5,627
Total Interest	17,153

Building and Improvements Interest Cost WS I.3

Item	Amount
Total Investment	98,625
Non-real Estate Debt:Equity Ratio	14.40%
Debt Portion	14,202
Effective Interest Rate	9.91%
subtotal	1,407
Equity Portion	84,423
Rate of Return to Equity	3.60%
subtotal	3,039
Total Interest	4,615

Long-Term Real Estate Debt Interest Cost WS I.4

Item	Acres	$/Acre	Total Value
Cropland	400	525	210,000
Real Estate Debt:Equity			14.40%
Debt Portion			30,240
Effective Interest Rate			9.91%
subtotal			2,997
Equity Portion			179,760
Rate of Return to Equity			3.60%
subtotal			6,471
Total Interest			9,828
Less: Interest on Buildings and Improvements			4,615
Total Interest, Land Only			5,213

Labor Requirements and Distribution of Hours WS 0.1

Item	Acres or Head	Hours per Ac. or per Hd. Man	Machine	Man	Machine	Seasonal Distribution of Man-hours J	F	M	A	M	J	Jl	A	S	O	N	D
Livestock	60	6.3		378	100	35	63	70	40	20	15	15	15	15	25	30	35
Crops:																	
Alfalfa-Grass Hay	150	2.45	2.04	368	306						167		201				
Winter Wheat	60	2.15	1.71	129	103						4	5	14	76			30
Barley	90	2.43	1.48	219	133				104		8		29		19		59
Pasture	60	0.22	0.18	13	11					13							
Summer Fallow	30	0.57	0.46	17	14						8	9					
Irrigation	300	2.00		600							180	300	120				
Labor Hours by Activity:																	
Livestock				378	100	35	63	70	40	20	15	15	15	15	25	30	35
Crop				1,346	566	0	0	0	104	13	367	314	364	76	19	0	89
Miscellaneous				345	82	7	13	14	29	7	76	66	76	18	9	6	25
Total Farm Work				2,069	748	42	76	84	173	40	458	395	455	109	53	36	149
Labor Hours by Worker:																	
Operator				1682		42	76	84	173	40	300	310	311	109	53	36	149
Family				285							100	85	100				
Contract Labor																	
Other Labor				102							58		44				

Source: Original computer data for "Enterprise Costs for Irrigated Crops in Gallatin County," and "Farm Management Data Manual," prepared by Cooperative Extension Service, Montana and Alberta Agriculture, Canada, respectively.

Buildings and Improvements WS 0.2

Item	Original Cost	Inventory Value	Annual Repairs	Annual Depreciation
Grain Storage	8,000	4,800	160	200
Machine Storage and Shop	18,000	10,800	360	450
Barn	8,450	5,070	169	211
Corrals	3,375	2,025	67	84
Water Development	675	405	13	16
Fences	10,125	6,075	202	253
Dwelling	50,000	30,000	1,000	1,250
Total	98,625	59,175	1,971	2,464

Machinery and Equipment WS 0.3

Item	Original Cost	Inventory Value	Annual Repairs	Annual Depreciation
Tractor, Diesel	35,050	21,030	1,591	402
Tractor, Gas	18,130	10,878	80	87
Truck	26,690	16,014	1,956	1,321
Truck, FWD	11,060	6,636	1,081	1,002
Swather	20,080	12,048	244	96
Baler, pto	10,960	6,576	741	453
Bale Wagon, pto	16,000	9,600	684	339
Combine	53,730	32,238	260	257
Drill	8,110	4,866	201	39
Tool Bar	3,400	2,040	57	16
Tandem Disk	5,320	3,192	200	29
Harrow	330	198	4	2
Ditcher	1,020	612	4	6
Ditch Closer	650	390	4	3
Miscellaneous	11,030	6,618	221	53
Automobile	10,000	6,000	n.a.	731
Total	231,560	138,936	7,328	4,836

1/ Repairs for the automobile are included in the estimate of all variable costs.

OTHER MAJOR ASSUMPTIONS TO THE FARM BUDGET ANALYSIS

Crop Budget Assumptions

1. The size of this representative farm is 400 acres. The crop mix and land use is as follows:

150 acres	Alfalfa-Grass Hay
60 acres	Winter Wheat, Gaines
90 acres	Barley
60 acres	Pasture, subirrigated
30 acres	Summer Fallow
10 acres	Wastage and Home site.

2. Average annual yields and prices for the crops are as follows:

Crop	Units	Yield/A.	Price/Unit
Alfalfa-Grass Hay	Tons	3.3	$67.50
Winter Wheat	Bu.	66.3	4.42
Barley	Bu.	69.3	2.70
Pasture	AUM	5.0	11.39

All yields are three-year simple averages for the years 1980, 1981 and 1982. All prices are Bureau of Reclamation normalized prices for fiscal year 1984.

3. Seeding rates are 60 pounds per acre for winter wheat, 80 pounds per acre for barley.

4. Chemical weed controls include 2,4-D and Fargo only.

5. A mill levy of 265 mills was used for computing taxes on machinery, buildings and land. Land taxes were based on assessed values of $37.05 and $20.51 for crop and pasture land, and grazing land, respectively.

6. Labor costs for hired labor was charged at $3.64 per hour. This rate includes room and board.

7. Machine storage and shop capacity were based on 3,000 square feet valued at $6.00 per square foot; grain storage was based on 10,000 bushels valued at $0.80 per bushel.

8. Total farm insurance was valued at $1,000 per year.

9. Automobile variable costs were based on $0.20 per mile.

10. Fuel, oil and lubricant costs for the tractor, swather and combine were based on 750, 450 and 35 hours, respectively. Diesel and gasoline are priced at $1.13 and $1.24/gallon, respectively.

11. Electricity (utility) costs were estimated to be $1,200.

12. Operator labor was charged at $5.00 per hour and family labor was charged at $3.64 per hour, the same as hired labor.

13. Fertilization rates for the various crops are as follows:

Crop	Nitrogen	Phosphorus
Alfalfa-Grass Hay	17 lbs/A	83 lbs/A
Winter Wheat	68	
Barley	70	50
Pasture	(from farmer survey $20/A)	

The costs for fertilizer are $0.24 and $0.21 for nitrogen and phosphorus (P205), respectively. Application costs are $2.25 per acre.

14. The irrigation costs included assume a flood irrigation system.

Livestock Budget Assumptions

1. The breeding herd consists of 50 cows and 2 bulls.

2. Ten percent of the cow herd is culled yearly. Bulls are replaced on a four-year basis.

3. A 92 percent calf crop (calves weaned/cows wintered) is obtained.

4. The herd is wintered for 180 days on a ration of hay.

5. Marketing weights for the calves are 525 and 500 pounds for steer and heifer calves, respectively.

6. All livestock prices are based on Bureau of Reclamation normalized prices.

7. Other livestock variable costs, including veterinary and medicine, utilities, and marketing are $685. Livestock taxes are $215.

Other Important Assumptions

1. Debt to equity ratios for real estate and non-real estate farm debt were based on statistics provided by Economic Indicators of the Farm Sector, Income and Balance Sheet Statistics, 1982 as published by the USDA for all debt including households. The debt:equity for real estate and nonreal estate were 14.4 and 32.5 percent, respectively.

2. Rates of return to equity were based on statistics provided by Economic Indicators of the Farm Sector, Income and Balance Sheet Statistics, 1982 as published by the USDA. The average rate of return of equity for 1970 through 1982 was 3.8 percent. (Updated to 3.60%)

3. The effective interest rate on operating capital and intermediate term debt is 14.90 percent, a normalized average of Production Credit Association annual average effective interest rates. This figure was supplied by the Bureau of Reclamation.

4. The effective interest rate on long term debt is 9.91 percent, an average effective interest rate for all long term debt outstanding that is held by the Federal Land Bank in Bozeman, Montana.

5. All formulas used in estimating machinery operating and ownership costs are employed in the Montana State University version of the Oklahoma State Crop Budget Generator.

6. Average annual gross earnings for Montana wage and salary employees was used as a proxy for operator and family labor and management in tabulating payment capacity. This assumes that only one family member is gainfully employed outside the household. This figure of $14,624 was reviewed and accepted as reasonable by the Bureau of Reclamation.

7. The analysis shows a positive payment capacity only when no return is paid to equity. In all scenarios examined for this study water payment capacity is generated from the return to equity.

8. Whenever reference is made to the Bureau of Reclamation in study, it refers to the Bureau of Reclamation's Billings, Montana office. the principal contacts have been A. Dickerman, T. Keller and K. Antonson.

Farm Perquisites (Income Equivalents) Contained in Budgets

Dwelling

Annual Repairs	$1,000
Depreciation	1,250
Debt Interest	714
Return on Equity	1,626

One-Half Automobile

Operation and Repairs	500
Depreciation	366
Debt Interest	242
Return on Equity	128

Ten Percent of Pickup Truck

Repairs	108
Depreciation	100
Debt Interest	54
Return on Equity	28
TOTAL	$6,116

8M087.113/0752H

EXHIBIT C

COMPILATION OF WATER PURCHASE CONTRACTS

MIDDLE CREEK PROJECT

WATER PURCHASE CONTRACTS

MIDDLE CREEK PROJECT

Term = 30 years

First Payment	Contract No.	Purchaser (as of 5-24-83)	Acre Feet
1951	1	Aakjer, Ralph & Nick	25
	2-A-1	Miller, John L.	50
	3	City of Bozeman	500
	4	City of Bozeman	550
	5-A	Kravik, Breta	25
	6-A	Schoenbach, Mary Benepe	30
	6-B	City of Bozeman	20
	7-A	Boylan, Richard J.	50
	8	Boylan, Boyd W.	25
	9-A-1	Bos, David & M.	50
	10	Doney, Frank R.	125
	11-A-1	Dusenberry, George E.	50
	11-A-2	Small Business Administration	50
	12	Dusenberry, Bert L., Jr.	75
	13-A-2	Landoe, H.B.	50
	14-A	Montana State University	100
	15-A-2	City of Bozeman	75
	16-A	MT Ag. Experiment Station	50
	17-A	Hougen, Roger	75
	18	Johnson, Carl G.	25
	19-A-2-A-1	Hume, Jack	100
	19-B-1	Harris, Marguerite K.	17
	19-B-2	Kirk, Charles H.	33
	21	Kessler, E.E.	100
	22	Kurk, Lester J.	25
	23	Kurk, A.J.	20
	24-A-1	Bos, John	50
	25-A-1	Kraft, Glen O.	50
	25-B	Kraft, Glen	50
	26	Kraft, Earl	100
	27-A-1-A-2	Graf, Eugene & G.	50
	27-A-2-A-2	Graf, Eugene & G.	50
	27-A-3	Lindvig, Einar, Regina & Harold	50
	28-A	Caprio, Joseph M. & Marilyn	100
	29	Nash, Jack	50
	30	Pasha, John R.	50
	31-A	Pasha, Mildred L.	50
	32-A	Pasha, Mildred L.	50
	33	Pasha, W.D.	50
	34	Pasha, W.D.	50
	35-A-1	McKean, Ramona	25
	36-A-1	Kraft, Ray	30

WATER PURCHASE CONTRACTS (continued)

MIDDLE CREEK PROJECT

Term = 30 years

First Payment	Contract No.	Purchaser (as of 5-24-83)	Acre Feet
	36-A-2	Kraft, Walter K.	70
	37	Smith, Stanley K.	50
	38-A-2	Haggerty, Ruth	25
	39-A-1	Derby, James E. & Emma	20
	40-A-1	Kirk, Marguerite	150
	41-A	Montana State University	50
	42-A-1-B	Westlake, George	50
	43-A-1-A-2	Landoe, H.B.	25
	43-A-1-B-2	Cawlfield, Dave R.	12.5
	43-A-2-A	Kraft, Earl & Melva	25
	43-A-2-B	Anderson, Richard & Mary	25
		1951 Subtotal	3652.5
1952	44-A	Hure, Jack	100
	46	Montana State University	300
	47-A-1	Jordan, Robert	25
	47-B	Wend, David and Alice B.	25
	48-A	Clark, Stan L.	50
	49-A-1-A	Campbell, John & P.	35
		1952 Subtotal	535
1953	50-A-1-A	Kirk, Marguerite	30
	50-A-1-B-2	Graff, Robert & H.	10
	51-A	Gallatin County	25
	52-A-2	Anderson, Richard & Mary	25
	52-B-2	Anderson, Richard & Mary	25
	53-A-2	Husemann, Ed	25
	54-A	Jordan, Robert & Mardella	50
	55-A	Bos, John	50
	56-A	Raffety, Lloyd & Mildred	15
	57-A-1	Fellerhoff, John A. & Ella H.	25
	57-A-2	Stenger, Edward & Helen	25
	58-A	White, Edna Tracy	50
	59-A-1	Jordan, Robert & M.	15
	60-A-1-A	Hargrove, Glen	50
	61-A-2	Landoe, H.B.	50
	62-A-1	Miller, Don	50
	63	Boylan, Paul F.	50
	66-A-1	Boyd, J.C.	75
		1953 Subtotal	645

WATER PURCHASE CONTRACTS (continued)

MIDDLE CREEK PROJECT

Term = 30 years

First Payment	Contract No.	Purchaser (as of 5-24-83)	Acre Feet
1954	67-A-1-A	Lewis, Yvonne Ellen	50
	68-A	Johnson, C. Glen	25
	69-A	Wolney, David A.	50
	70-A-1-B	City of Bozeman	50
	72	Westlake, Myron M.	50
	73	Bradley, James C.	50
	74-A	City of Bozeman	10
	75-A-1	Westlund, George F. & Nancy J.	50
	76-A-2	Bennett, Marshall a/o Luzann	50
		1954 Subtotal	385
1955	77	Dyk, Peter S.	200
	78	Cawlfield, Dave R.	40
	79	Sabo, Dr. F.	100
	81	Cline, C.E.	50
		Lloyd & Mildred	50
		Lang, Vernon J.	100
	85-A-1	Walker, Edwin	30
	86	Hoppel, Fred G.	20
		1955 Subtotal	590
1956	20-A-1-A	Miller, Don	25
	20-B-1	Dogterom, C.A. and/or McChesney, A.L.	50
	20-C	Wolney, David A.	50
	88	City of Bozeman	1450
	89-A-1-B	City of Bozeman	50
		1956 Subtotal	1625
1958	45-A-1	Lane, Thomas E. & Robert D.	100
	64-A-1	Anderson, Richard & M.	15
	71-A-1	Hume, Jack	50
	83-A-1	Vincent, Tom E. & Marjorie S.	50
	90-A	McCrosson, John W., Jr.	12.5
	91-A	Walker, Edwin & Hilda H.	20
		1958 Subtotal	247.5

WATER PURCHASE CONTRACTS (continued)

MIDDLE CREEK PROJECT

Term = 30 years

First Payment	Contract No.	Purchaser (as of 5-24-83)	Acre Feet
1959	92-A-2	Lee, Clara B.	40
	92-B	Amunrud, Leroy & Dorris	20
		1959 Subtotal	60
1960	93-A	Cattrell, David	20
	95-A	Enger, Lawrence & M.	20
		1960 Subtotal	40
1961	94	Raffety, Lloyd & Mildred	10
		1961 Subtotal	10
1966	96-A	Bennett, Marshall B. and/or Ciluzann	20
		1966 Subtotal	20
		TOTAL CONTRACTS	7,810

Source: Department of Natural Resources and Conservation, Water Projects Accounting System, 0422-Middle Creek Water Users Association.

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EXHIBIT D

GLOSSARY OF TECHNICAL TERMS

EXHIBIT D

GLOSSARY OF TECHNICAL TERMS

500-Year Flood - The flood that can be reasonably expected to exceed once every 500 years.

Alluvium - A general term for all soil deposits resulting from the operation of modern rivers, thus including the sediments laid down in riverbeds, floodplains, lakes, and at the toe of slopes and estuaries.

Auxiliary Spillway - That spillway used very infrequently.

Baffle or Chute Blocks - Structural blocks used to dissipate energy.

Baffled Apron Drop Spillway - A baffled chute used to drop water from one level to another where a stilling basin is undesirable.

Benefit/Cost Ratio - The ratio of economic benefits to the costs over the life of the project.

Consumptive Use - Consumptive use, often called evapotranspiration, is the amount of water used by the vegetative growth of a given area in transpiration and building of plant tissue and that evaporated from adjacent soil or intercepted precipitation on the plant foliage in any specified time.

Conveyance Efficiency - Ratio of volume of water delivered to farm headgates to the volume of water diverted.

Dissolved Solids - Salts found in dissolved or ionic form in water commonly measured in parts per million.

Dynamic Stability Analysis - An engineering calculation of the resistance of an earth slope to sliding. This calculation considers the dynamic forces on the earth slope induced by seismic activity.

Effective Rainfall - Precipitation falling during the growing period of the crop that is available to meet the consumptive water requirements of crops.

End Sill - Structural component of a stilling basin which dissipates energy.

Farm Perquisites - Income equivalent which are a spin-off from farming including housing and private use of automobiles.

Freeboard - The vertical distance between the top of the dam and the maximum water surface elevation which is provided to protect the dam embankment from overtopping due to wave runup and wind setup.

Gabions - A steel wire cage filled with stones used for soil stabilization.

Growing Season - That period of time in which the crop is growing and consuming water, usually extends from the last killing frost in the spring to the first killing frost in the fall or until the crop reaches maturity.

Induced Infiltration - Infiltration of water from a streambed due to lowering of the water table adjacent to and under the stream.

Irrigation Efficiency - The percentage of applied or diverted irrigation water that is stored in the soil and available for consumptive use by the crop. When the water is measured at the farm headgate, it is called on-farm-irrigation efficiency; when measured at the field, it is designated as field-irrigation efficiency; and when measured at the point of diversion, it may be called project or unit-efficiency.

Jet Pump - A pump which forces a motive fluid through a nozzle creating a low pressure area. This introduces the suction fluid into a diffuser where the high velocity of the jet is changed into pressure.

Labyrith Weir - A sawtooth patterned inlet which allows increased spillway efficiency.

Marginal Value - Goods valued at their cost of production.

Maximum Water Surface Elevation - The maximum reservoir pool elevation attained during routing of the spillway design flood.

National Geodetic Vertical Datum - A national datum which forms the basis for the computation of horizontal survey control in which the curvature of the earth is considered.

Net Irrigation Requirement - The depth of irrigation water, exclusive of precipitation, stored soil moisture, or ground water, that is required consumptively for crop production.

Nonerodible Velocity - The greatest mean velocity which will not cause erosion of a channel.

Normal Water Surface Elevation - The reservoir pool elevation corresponding with the top of the active storage pool (the portion of storage used to supply agricultural and municipal needs).

Normalized Prices - Agricultural commodity prices which are adjusted statistically to minimize the effect of price fluctuations and localized market differences.

Ogee Crest - A spillway crest which is Ogee or s-shaped in profile and allows high discharge efficiency.

Overland Flows - The component of runoff which travels overland.

PVC - Poly Vinyl Chloride.

Payment Capacity - The ability to pay for the annual costs of irrigation after considering farm expenses, interest on indebtedness and allowable returns to ownership.

Phreatic Water Surface - A phreatic surface develops within a soil mass which is at least partially saturated. This surface is the location at which the pore water pressure is atmospheric. A similar term denoting approximately the same location is water table.

Present Value - Value at time = 0 of the amount earned if invested at the given interest rate uniformly over a given period.

Prestressed Concrete - Precast, structural elements in which reinforcing is provided by high strength steel which is pretensioned.

Principal Spillway - That spillway used frequently on a year-to-year basis.

Probable Maximum Flood - The flood that may be expected from the most severe combination of critical meteorological and hydrologic conditions that are reasonably possible in the region.

Producer Surplus - The increased economic value of a commodity over that actually paid.

Reinforced Earth - A patented system of retaining wall construction. Retaining walls are formed with concrete panels supported by steel reinforcing straps extending from the panel horizontally into the wall backfill.

Returns to Equity - An opportunity cost partially offsetting the return if the equity funds were invested at the going interest rate.

Returns to Labor - That portion of net farm income allocated to the owner and his family for their labor.

Returns to Management - A return allowed for the additional expertise to own and operate a business.

Right and Left Abutments - The abutments are the natural valley walls into which the embankment abuts. The right and left convention is determined by looking downstream.

Riprap - A wall or zone of material usually composed of loose rock massed together to provide resistance to erosion caused by the movement of water.

River Basin Efficiency - Ratio of water consumed by crops, non-beneficial vegetation and water returning outside of growing season to that volume of water diverted less recoverable return flows.

Service Area - The gross area to which water can be delivered.

Sinking Fund Depreciation - A uniform amount invested each year at a given interest rate which will repurchase the item at the end of its life less salvage value.

Specific Yield - The quantity of water that a unit volume of sand or gravel will give up when drained by gravity.

Spillway Design Flood - The largest flood that need be considered in the evaluation of a given project.

Static Stability - An engineering calculation of the resistance of an earth slope to sliding. This calculation considers the physical and engineering properties of the materials involved. The driving force (causing sliding) is the static weight of the soil.

Tailrace - The channel downstream of a hydraulic structure.

Transmissivity - Rate of flow in gallons per day through a vertical section of an aquifer whose height is the thickness of the aquifer and whose width is one foot with a hydraulic gradient of 1.0.

Wave Runup - Vertical height above the stillwater level that water reaches because of waves.

Wind Setup - The vertical rise in the stillwater level on the leeward side of a body of water caused by wind stresses on the surface of the water.

EXHIBIT E

SPILLWAY HYDRAULICS

EXHIBIT E
SPILLWAY HYDRAULICS

PRINCIPAL SPILLWAY

The principal spillway has five major components, as shown on Exhibits A-1, A-3, A-4, and A-5. These are the inlet, chute, stilling basin, channel, and baffled apron drop. The hydraulic analysis of each will be discussed briefly in the following paragraphs.

Inlet

The crest was designed as a one cycle labyrinth weir using the method outlined in Hay and Taylor, "Performance and Design of Labyrinth Weirs", ASCE J. Hyd. Div., November 1970. The 143-foot long crest provides 3.86 times the weir length of a straight weir within the chute. The crest is trapezoidal in cross section with a 3H:1V sloping upstream face and vertical downstream face. For this slope of weir, Brater-King, Handbook of Hydraulics, 6th Edition, McGraw Hill, 1976, gives a relatively constant discharge coefficient of 3.57. The height of the weir above the upstream base (P) is 13.3 feet. The resulting unsubmerged rating curve over the weir had flows between 3.00 and 4.02 times the discharge of a straight sharp crested weir across the inlet.

The downstream apron was located 4 feet below the crest to cause submergence for flows greater than the 500-year routed peak of 1,000 cfs. Downstream water surface profiles were analyzed using step backwater computations beginning at critical depth a distance of three times the critical depth upstream of the vertical curve. For this section a slope of 0.0 and a Manning's "n" of 0.015 were used. Submergence of the weir was computed by energy balance across the submerged weir,

assuming a headloss of 0.2 times the difference in velocity head between the reservoir and a section at the downstream apexes of the labyrinth.

Flow entering the principal spillway during the PMF is restricted by an orifice wall extending down from the center of the bridge. During the 500-year flood, the wall maintains a freeboard of 3 feet above the water surface in the inlet for wave clearance. During the PMF, however, the orifice is activated to limit flows to 3,400 cfs, thereby reducing the required chute and stilling basin capacity.

Chute

The vertical curve and chute section were designed using guidelines given in USBR, Design of Small Dams, 2nd Edition, Revised 1977. The vertical curve was designed for the maximum flow of 3,400 cfs to avoid structural damage during the PMF. Freeboard, however, was based on the design flow of 1,000 cfs. Wall heights through the section were selected as the greater of the PMF water surface and the 500-year water surface plus freeboard. It was felt that minor damage due to wave overtopping was acceptable during the PMF. The water surface profiles through this section were approximated by using gradually varied flow with a Mannings' "n" of 0.008, as recommended by SCS, Engineering Handbook Section 14, Chute Spillways, Revised October 1977, beginning with critical depth at the entrance to the vertical curve.

Stilling Basin

The stilling basin was designed as a USBR Basin III, using criteria given in USBR, Hydraulic Design of Stilling Basins and Energy Dissipators, EM #25, 1978, for a design flow of 1,000 cfs. Stilling basin wall heights were checked for overtopping during the PMF and found to be satisfactory. Low tailwater

during the PMF would cause the hydraulic jump to sweep out of the stilling basin, causing some possible damage from undermining. Due to the remoteness of the PMF and the slow acting destruction from undermining of the downstream end, it is felt that this damage is acceptable.

Tailwater was modeled using COE, Generalized Computer Program HEC-2, Water Surface Profiles, Davis, CA, September 1982. The floor elevation was set based on full conjugate depth for the design flow of 1,000 cfs. Lower flows were checked to assure that stilling action would be effective for all flows less than design flow.

Riprap beyond the stilling basin was designed using criteria given in USBR, Design of Small Canal Structures, 1978, for chute outlet protection.

Channel

The channel was designed to minimize earthwork and prevent erosion up to the rated flow of 1,000 cfs. The inlet sill elevation to the baffled apron drop was varied to keep velocities in the channel below 5 fps. Since the highest velocities occur in the 200 feet just downstream of the stilling basin and large excavations in that area are undesirable, the baffled apron inlet sill was located above the lowest point in the channel. An adverse slope exists between the meadow and baffled apron inlet. Drainage in this section will be accounted for in final design.

The dike across the meadow is designed to overtop during floods greater than the design flood. This minimizes the required capacity of the baffled apron drop. The top of the dike was therefore placed at the computed 500-year water surface. The PMF water surface profile was computed using the HEC-2 split

flow routine. It was assumed that the dike would remain intact for conservative design of the baffled apron drop. Manning's "n" values were taken from Chow, Open Channel Hydraulics, McGraw Hill, 1959, and ranged from 0.04 for high retardance grassed channels to 0.1 for trees and brush on the side slopes.

Baffled Apron Drop

The baffled apron drop was designed using techniques found in USBR, EM #25. A design flow per unit width of 35 cfs per foot was chosen. From the HEC-2 split flow analysis it was determined that a maximum discharge of 1,500 cfs would enter the baffled apron drop during the PMF, giving a unit discharge of 50 cfs per foot, which is less than the maximum allowable 60 cfs per foot. The inlet apron was designed to give a maximum 5 fps velocity during the 500-year flood. Wall height at the inlet was chosen to extend slightly above the water surface during the PMF.

Inlet and outlet riprap were selected using the USBR, Design of Small Canals criteria for chute outlet protection. It can be seen from Exhibit A-1 that water exiting the baffled apron drop must make a sharp bend to intersect the channel. It is probable that large eddies will form in the tailwater area. Riprap is therefore specified on all slopes in the affected areas. This will also provide protection for the outlet works.

The water surface profile for the peak flow occurring during the routed 500-year flood is plotted on Exhibit A-3.

AUXILIARY SPILLWAY

The auxiliary spillway was designed to safely pass the PMF, minimize environmental impact, and minimize excavation. The hydraulic design was performed using COE and USBR criteria, and checked using HEC-2.

An excavation and dike downstream of the existing reservoir access road were necessary to direct the flood away from the toe of the dam. The depth and width of cut were selected to fit the existing topography and carry the flow within natural banks at the most downstream excavation. The top of the dike follows the energy grade line of the maximum routed PMF flow, as computed with HEC-2. Since the maximum velocity along the dike was computed to be 12.3 fps a layer of 22 inch (nominal diameter) riprap was specified on the exposed face, as recommended by USBR EM #25.

For all flows less than the design flow, critical depth occurs where the channel crosses the existing reservoir access road.

Since raising the dam 10 feet would necessitate a 8.6% grade on the access road between the auxiliary spillway crossing and the dam, it was decided to route the access road up the auxiliary spillway. Using a 24-foot road bed with 2-foot shoulders and 4-1/2-foot wide drainage ditches on both sides gives a minimum channel bottom width of 37 feet. Due to the shape of the drainage that the auxiliary spillway follows, a deep, narrow excavation will require less excavation than a wide shallow excavation. For this reason, a channel with the minimum bottom width was chosen for as much of the spillway as possible.

The crest of the spillway was chosen to be circular in plan to fit the terrain, provide aesthetic appeal, and provide smooth transition to the narrow channel. The crest elevation was chosen to be equal to the 500-year peak reservoir water surface elevation. The length of the crest was chosen using HEC-2 beginning with critical depth at the crest and ending with a still pool energy grade line equal to the maximum water surface elevation for the peak routed PMF outflow.

The transition from the crest to the channel was designed using USBR, Design of Small Dams convergence criteria based on Froude number. The elevations of the end of transition invert and the end of channel invert were found by iteration. It was found that a minimum slope in the channel section caused by a one-foot drop over its length would provide adequate drainage, maximize hydraulic efficiency, and minimize excavation. The end of transition invert elevation was then varied in HEC-2 until the depth at the crest was critical for the minimum flow. The length of transition was adjusted in each iteration to account for the changes in Froude numbers at the transition end points. A Manning roughness coefficient of 0.04, expansion coefficient of 0.5, contraction coefficient of 0.3 and side slopes of 2.5H:1V were used for the entire spillway.

The effect of log jamming at the end of the transition was investigated. It was found that by placing a 5-foot high obstruction across the bottom of the channel, the reservoir water surface would rise to within 0.15 feet of the top of the dam at peak PMF discharge. Since the spillway flow at the point of obstruction would have a channel velocity of 23.6 fps, a depth of 23.9 feet, and a top width of 131 feet, the erosive power of the water in that section would be tremendous. Even if a log jam could withstand the tremendous static and dynamic forces, it is doubtful that its foundation would. For these reasons, it is felt that debris will not be a problem in this spillway.

The plan view of this spillway is shown in Exhibit A-1. The profile with the maximum flow water surface profile is shown in Exhibit A-7.